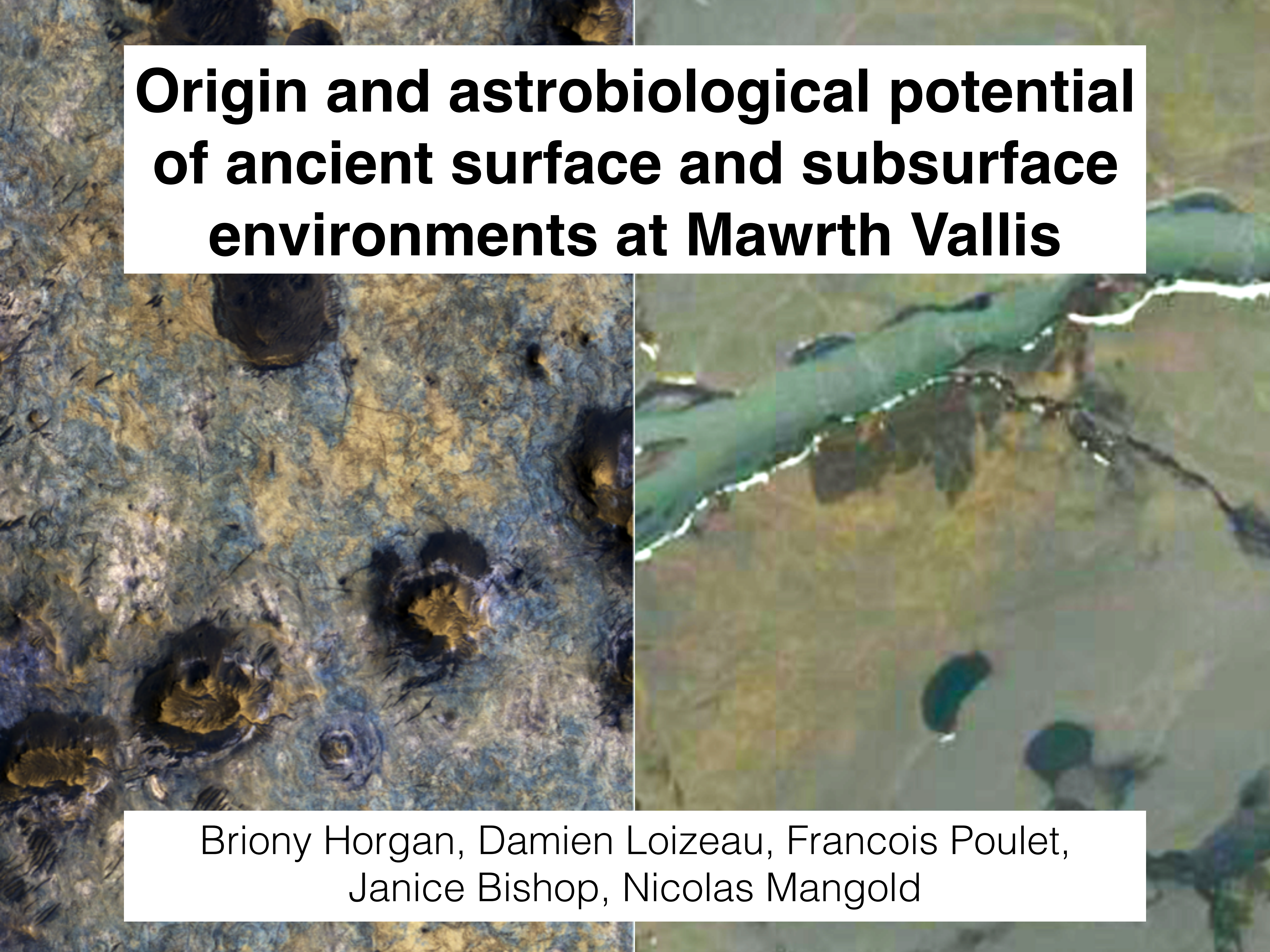
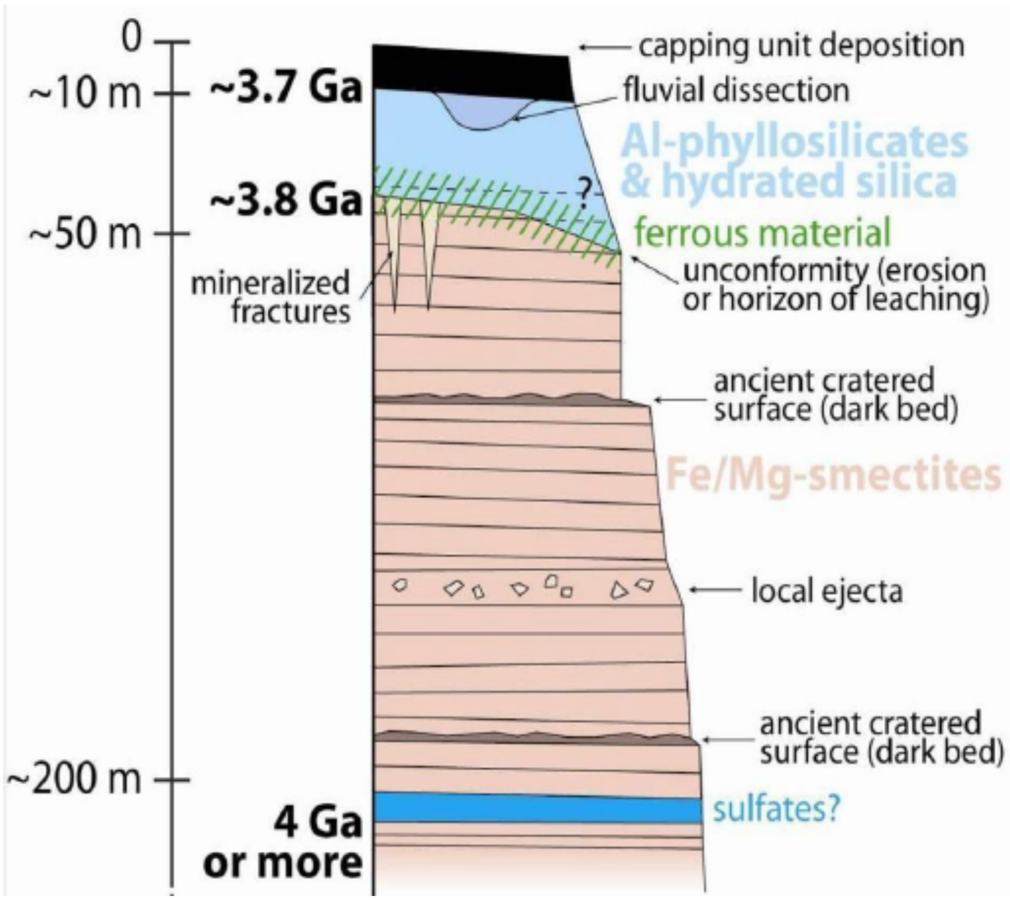
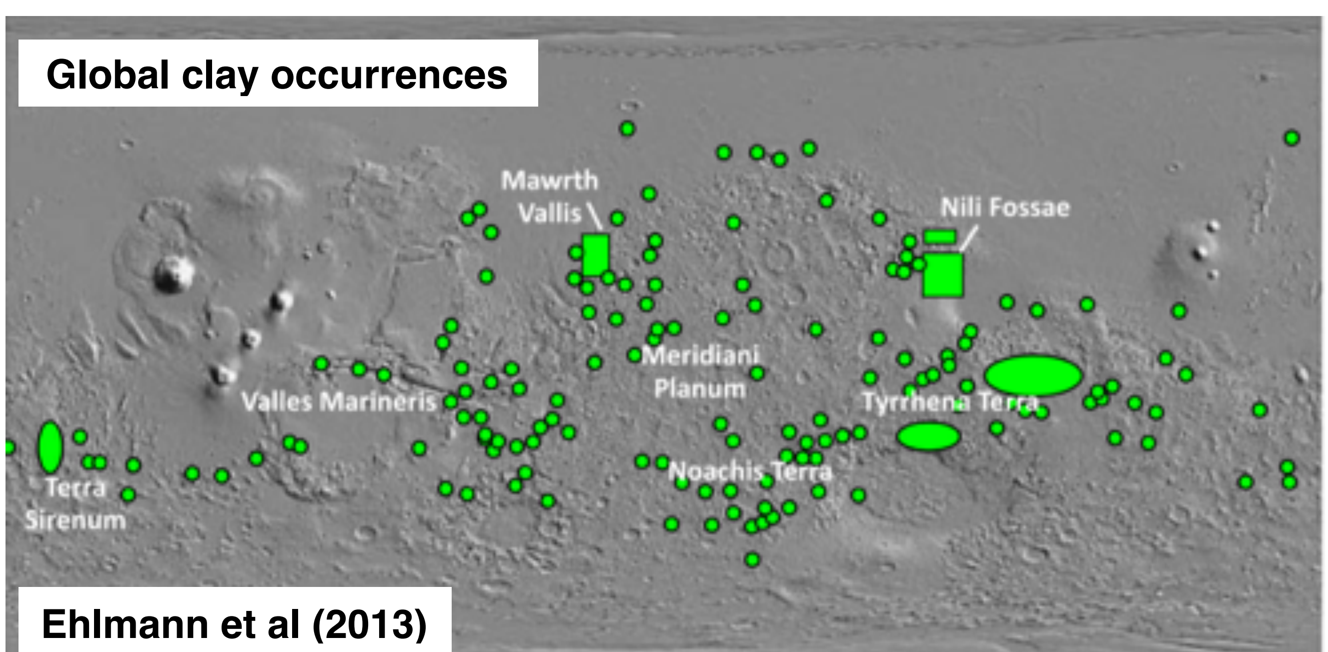


Origin and astrobiological potential of ancient surface and subsurface environments at Mawrth Vallis

Briony Horgan, Damien Loizeau, Francois Poulet, Janice Bishop, Nicolas Mangold

The presence of thick, apparently in place Fe/Mg-smectite deposits may link Mawrth to more global crustal smectites





Layering, sulfate interbeds, and cratered surfaces all suggest a long-term depositional sequence.

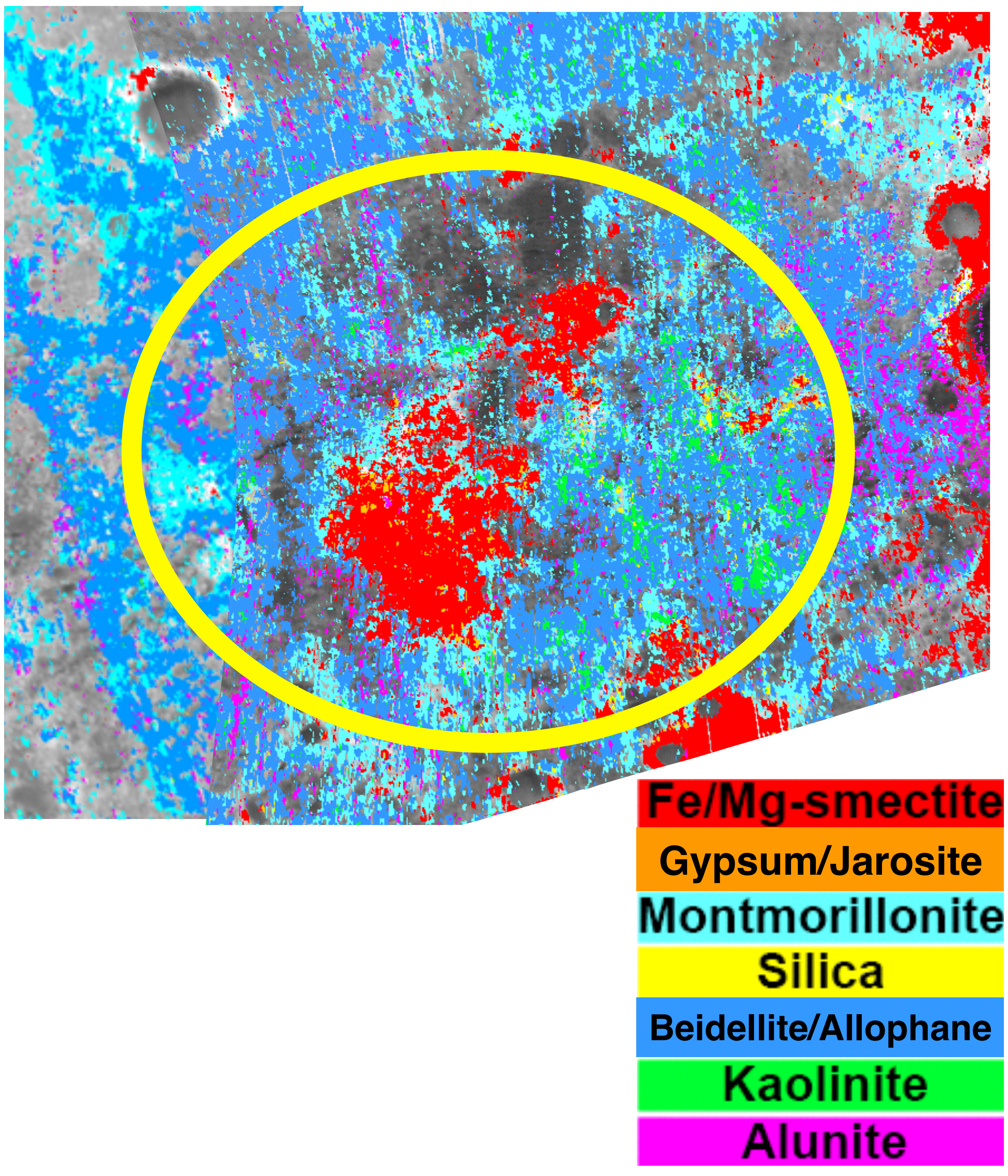
Hypotheses for the origin of the Fe/Mg-smectites:

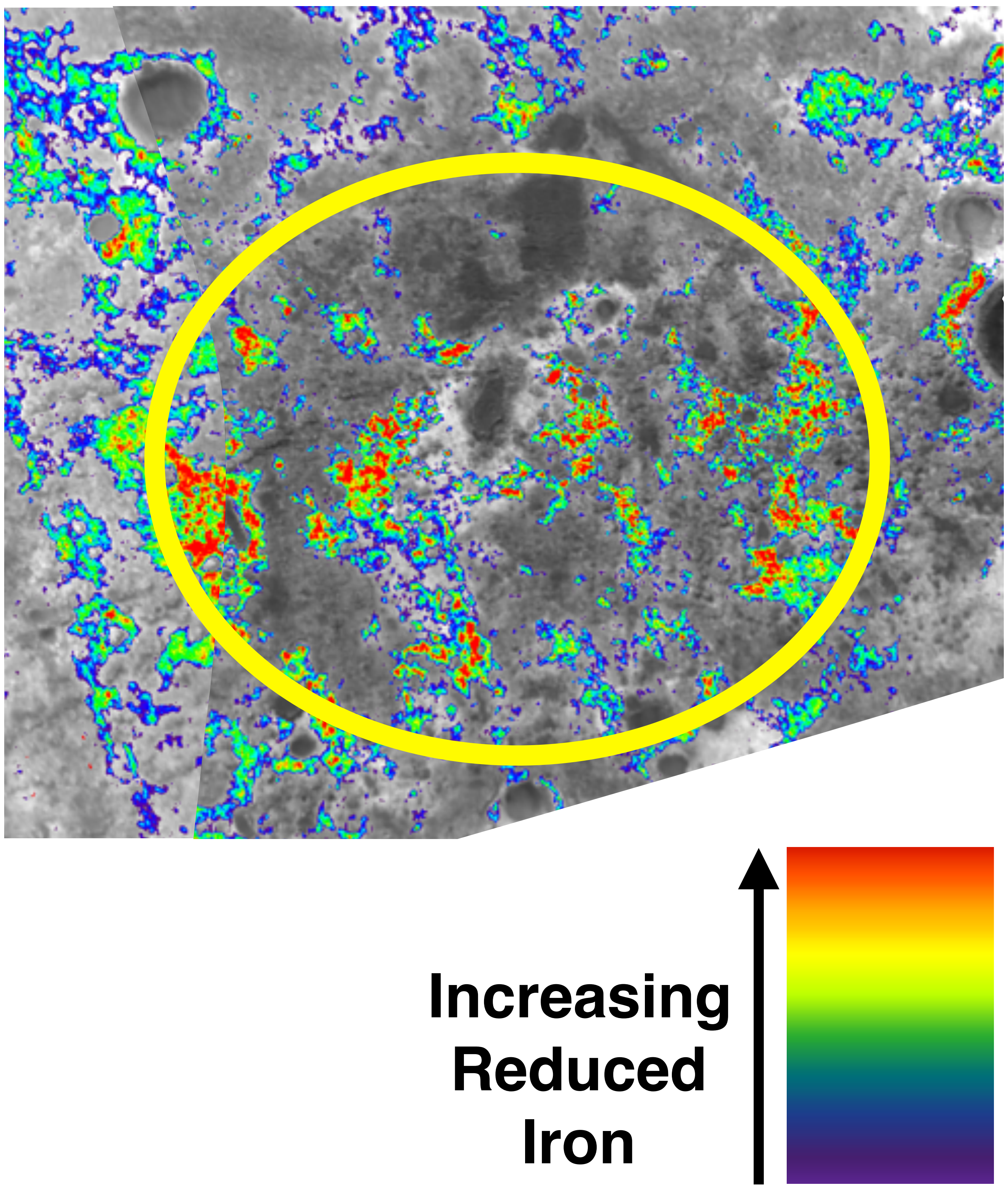
- Hydrothermal alteration
- Deep crustal aquifers
- Submarine alteration
- Pedogenic alteration of ultramafic volcanic sequence

Compared to other crustal clays, Mawrth is less chloritized and more clearly in place - many others are exposed by impact.

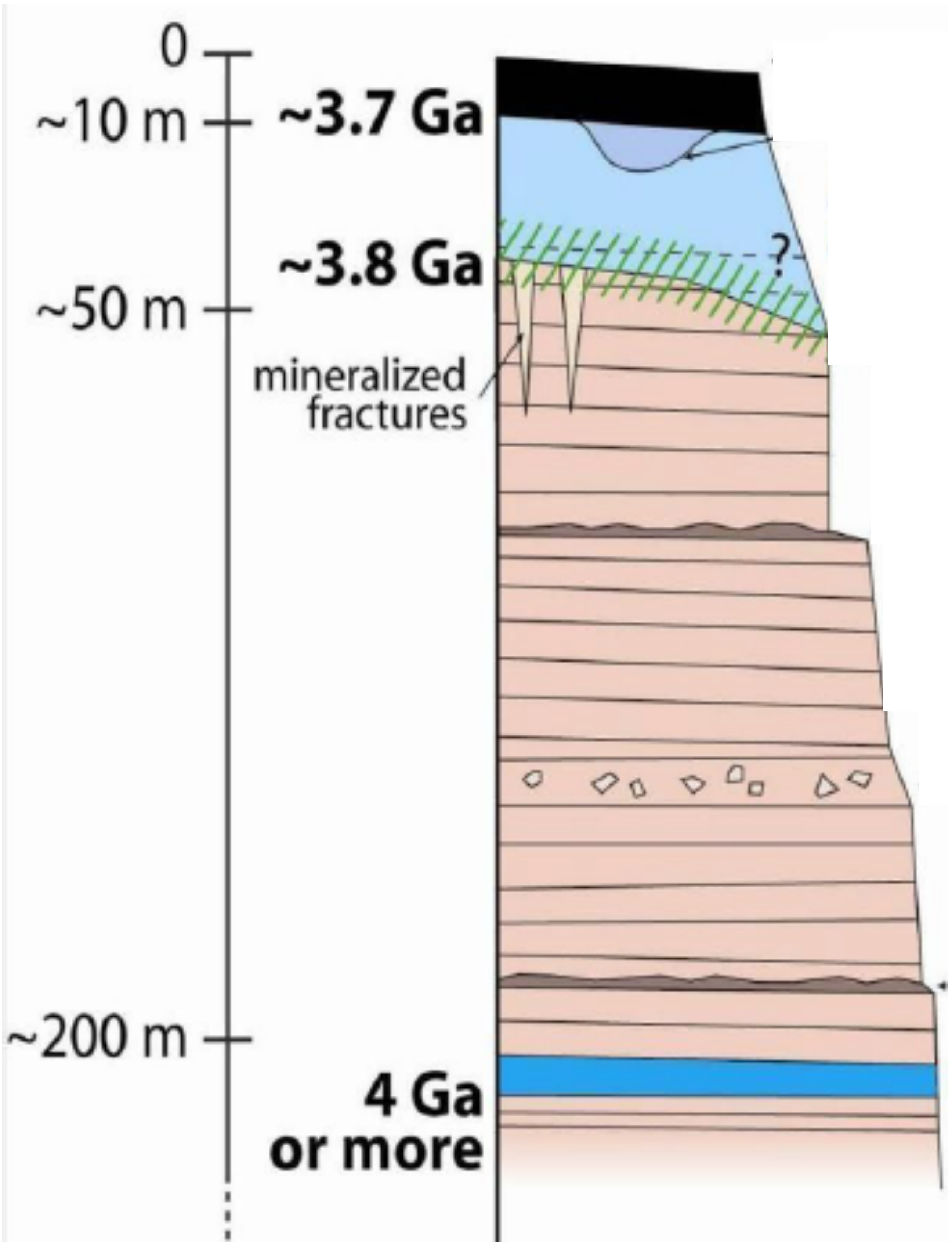
Are the Mawrth Fe/Mg-smectites a more pristine example of global crustal clays?

The Al-unit exhibits significant mineral diversity consistent with diverse environmental conditions





What is the relationship between the Fe/Mg-smectites and the Al-unit?



The Al-unit significantly postdates the Fe/Mg-smectites. Mawrth Vallis was incised and Oyama crater impacted before the formation of the Al-unit.

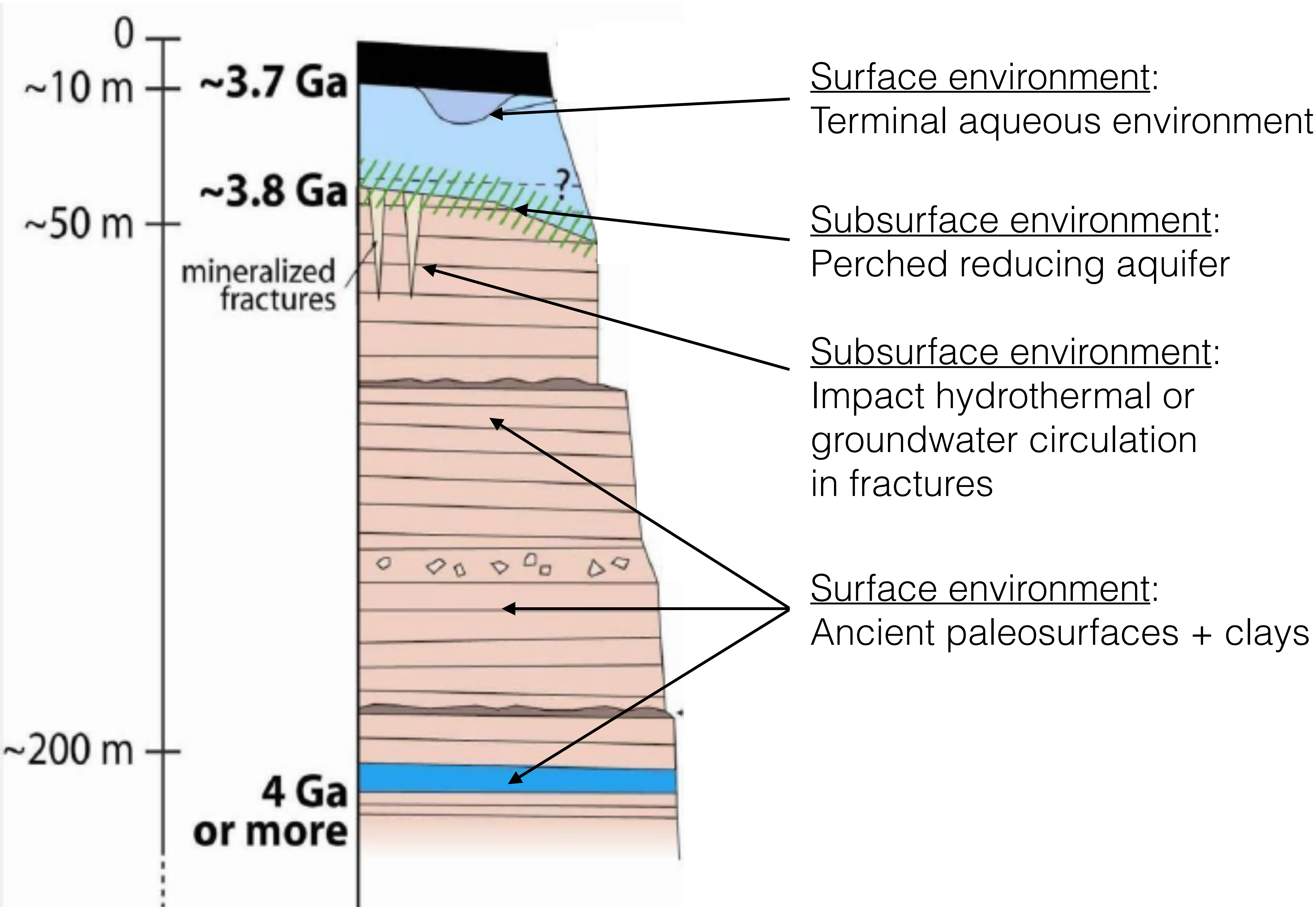
<u>Hypotheses:</u>

(1) The Al-unit is a leaching profile formed within the Fe/Mg-smectites

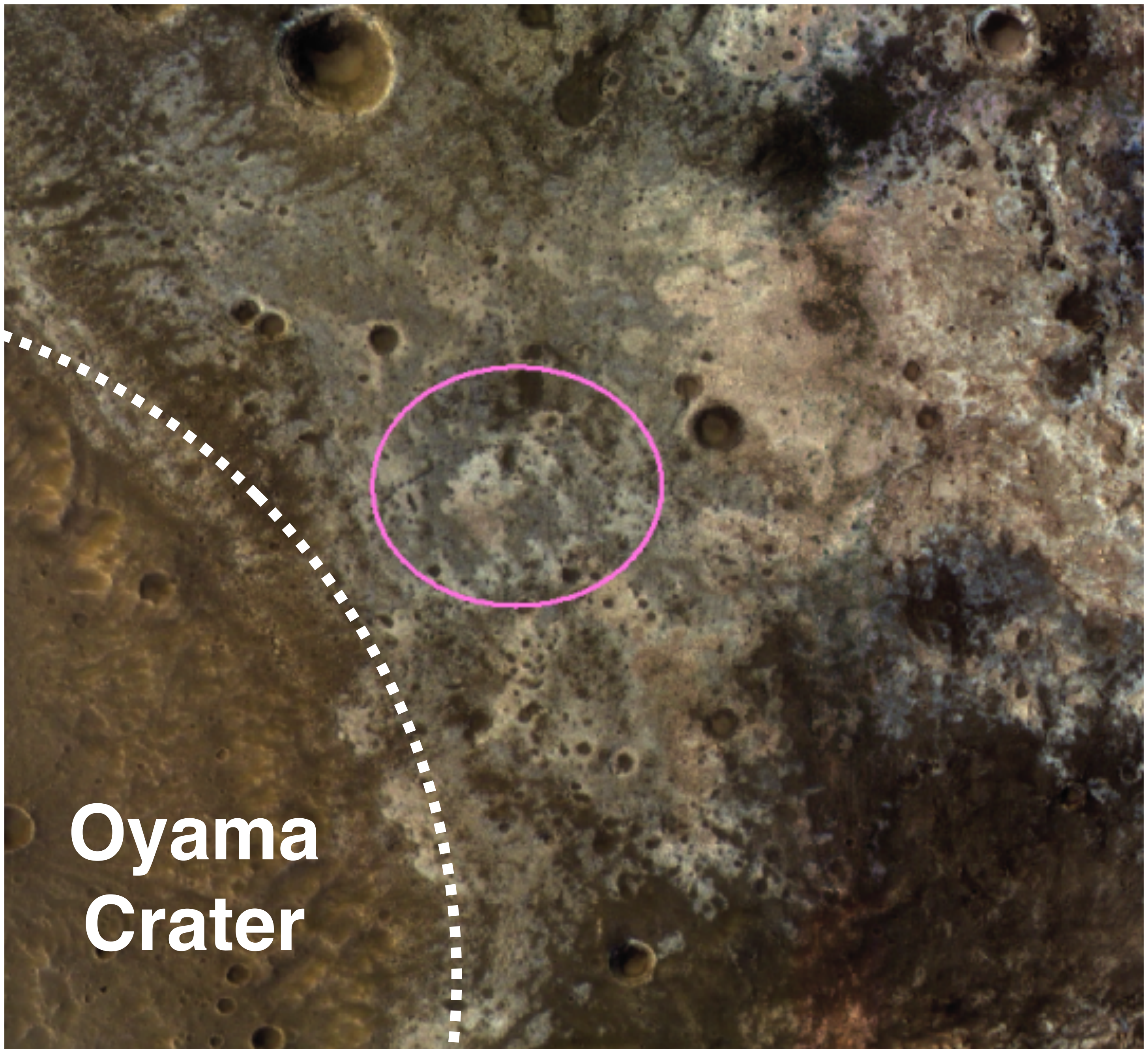
(2) The Al-unit is a separate, later deposit (e.g., a weathered ignimbrite or paleosol sequence)

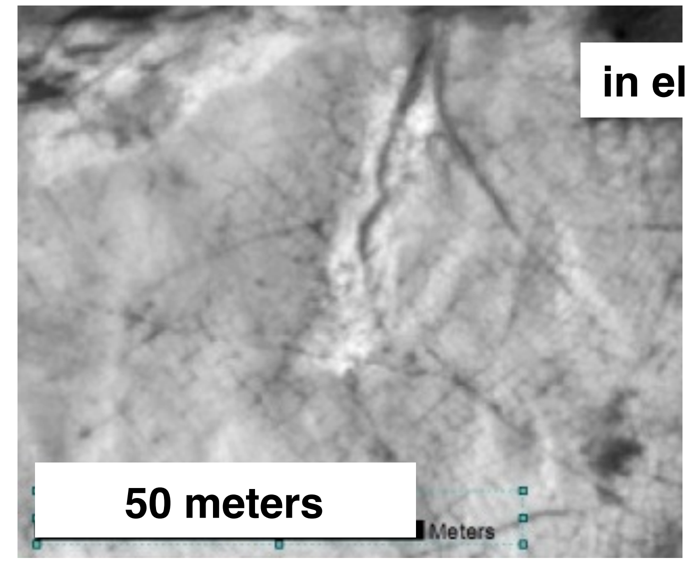
Lack of large fractures and lack of layering in Al-unit may support a separate origin from Fe/Mg-smectites.

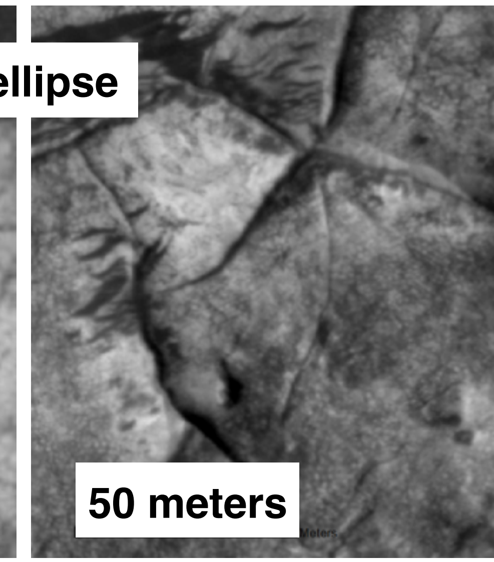
Mawrth Vallis preserves mineral and geomorphic evidence for both surface and subsurface habitable Noachian environments

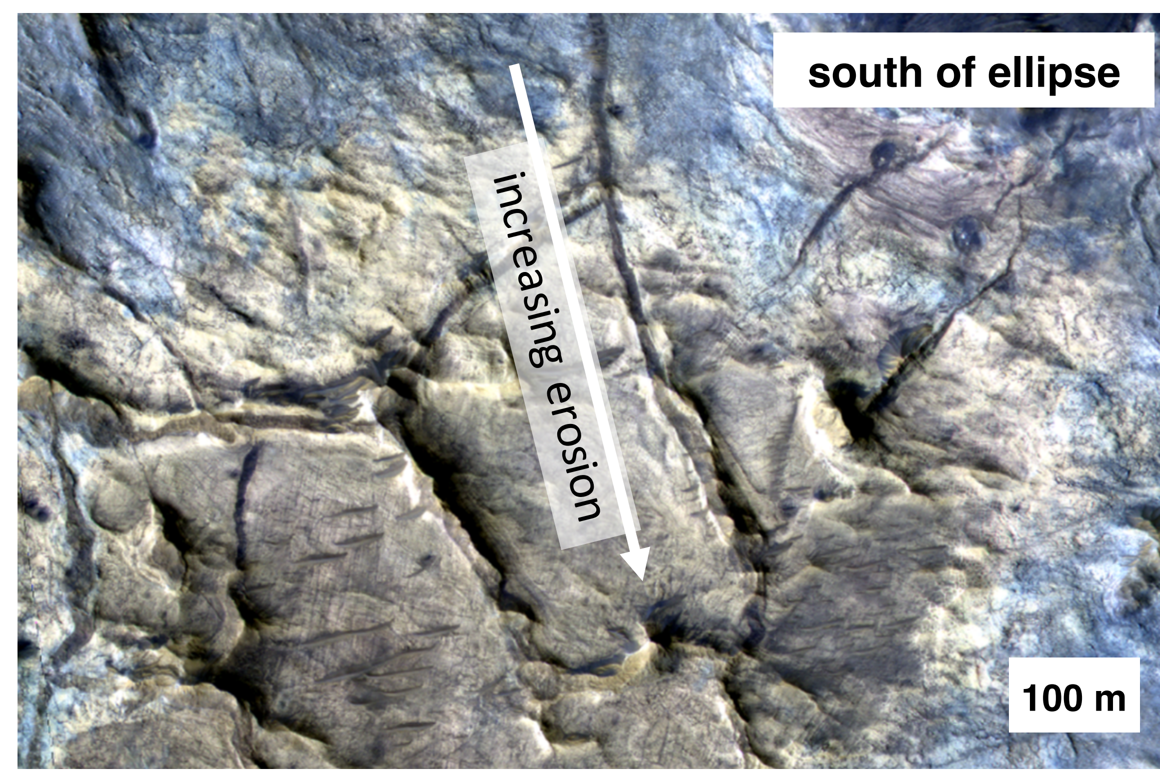


Subsurface environment #1:
Resistant fractures and halo-bounded veins are consistent with mineral precipitation and leaching in an aquifer or hydrothermal system





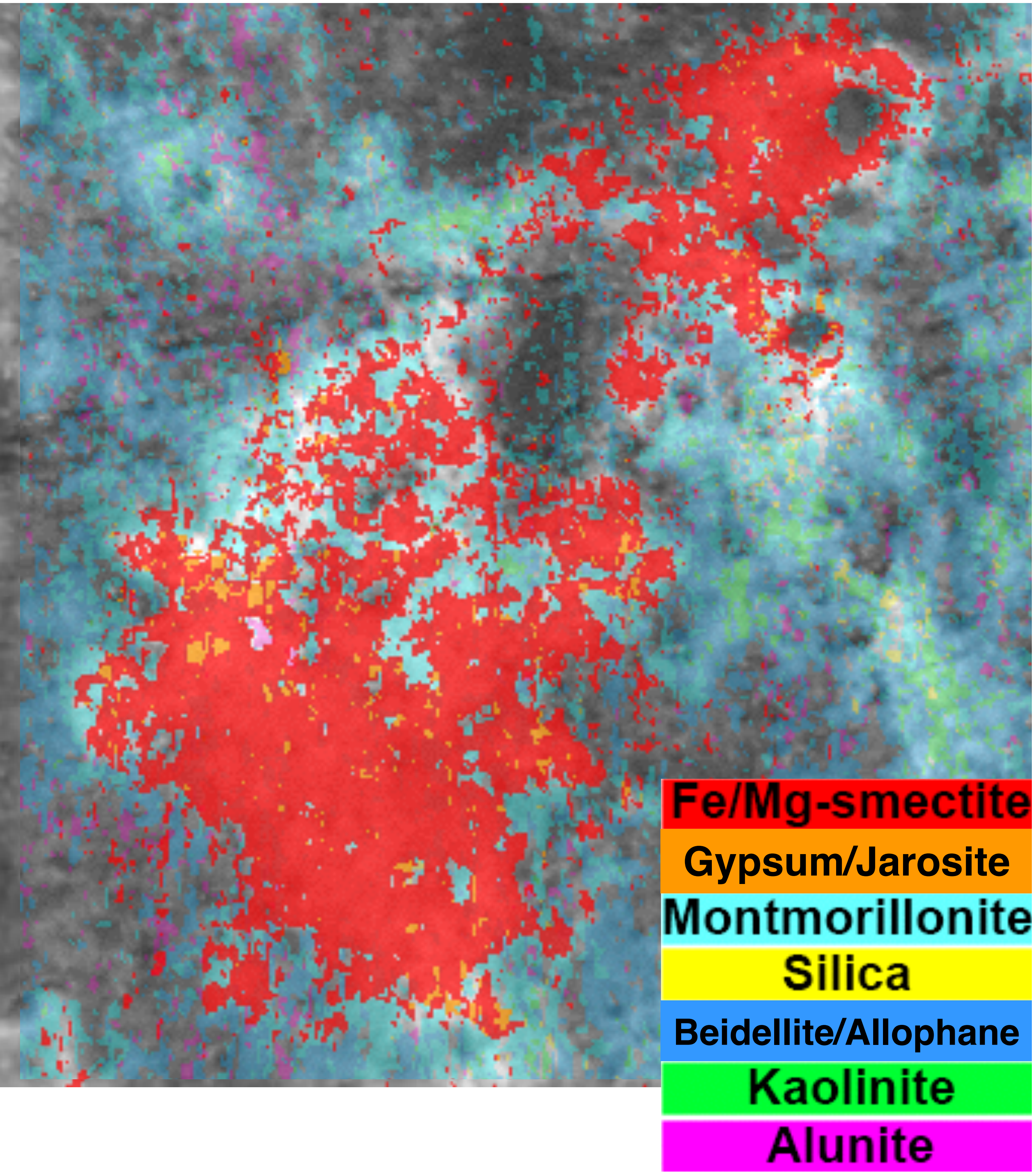


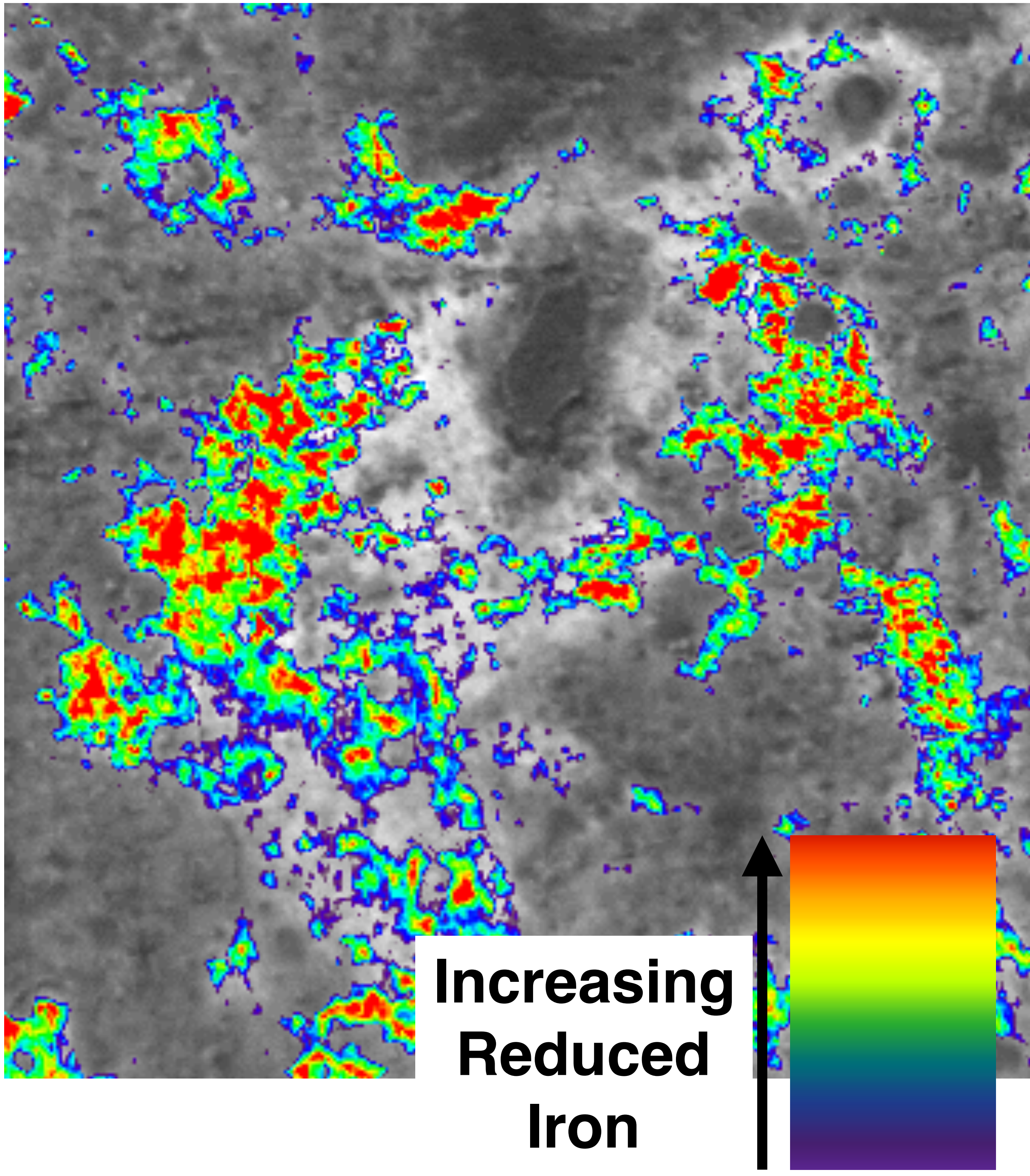


Biosignature preservation in subsurface environments is enhanced by mineral precipitation

Subsurface environment #2: Ferrous alteration zone at the top of the Fe/Mg unit is consistent with a reducing aquifer perched at the contact

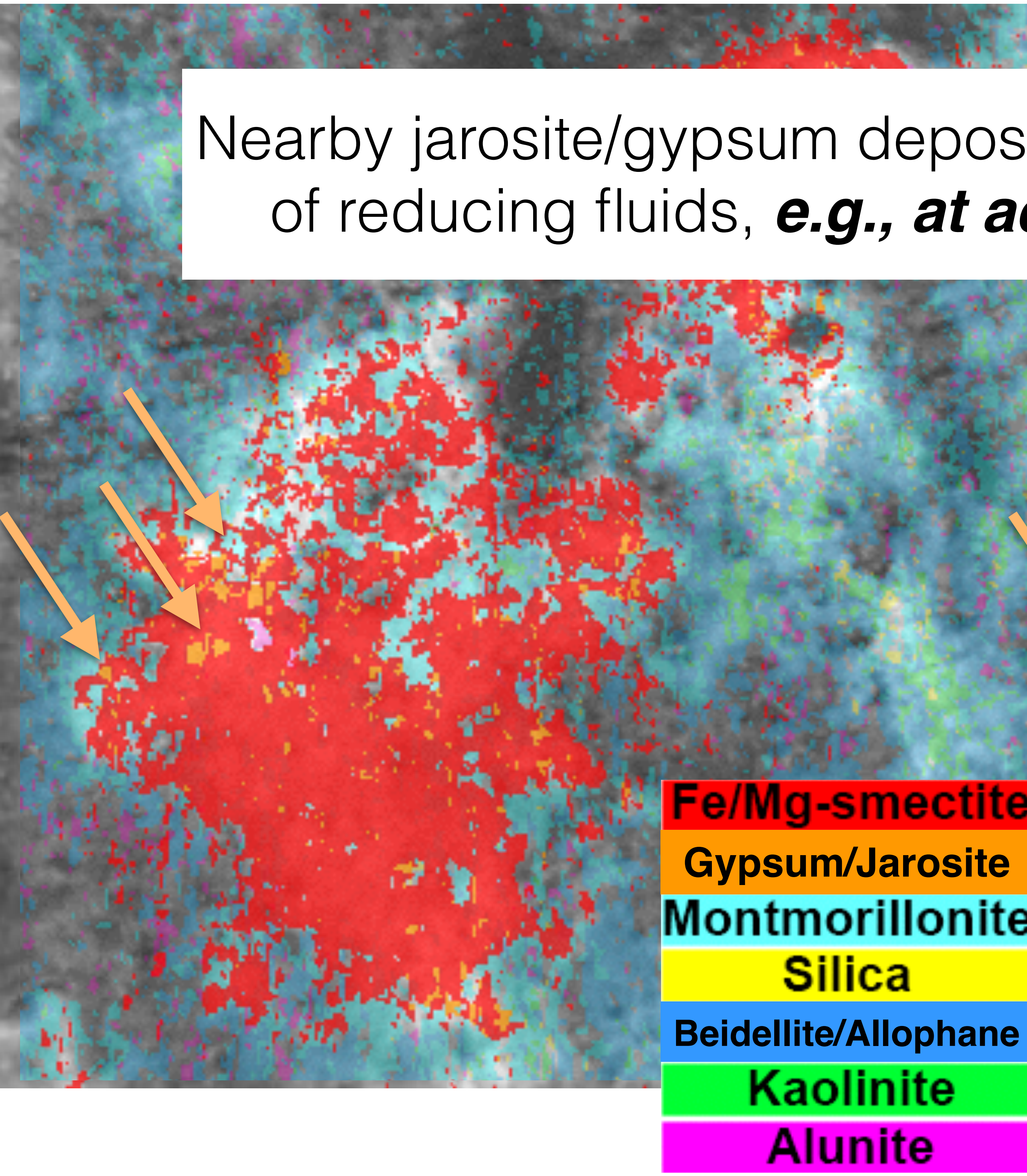
For spectral analysis: Bishop et al (2013)

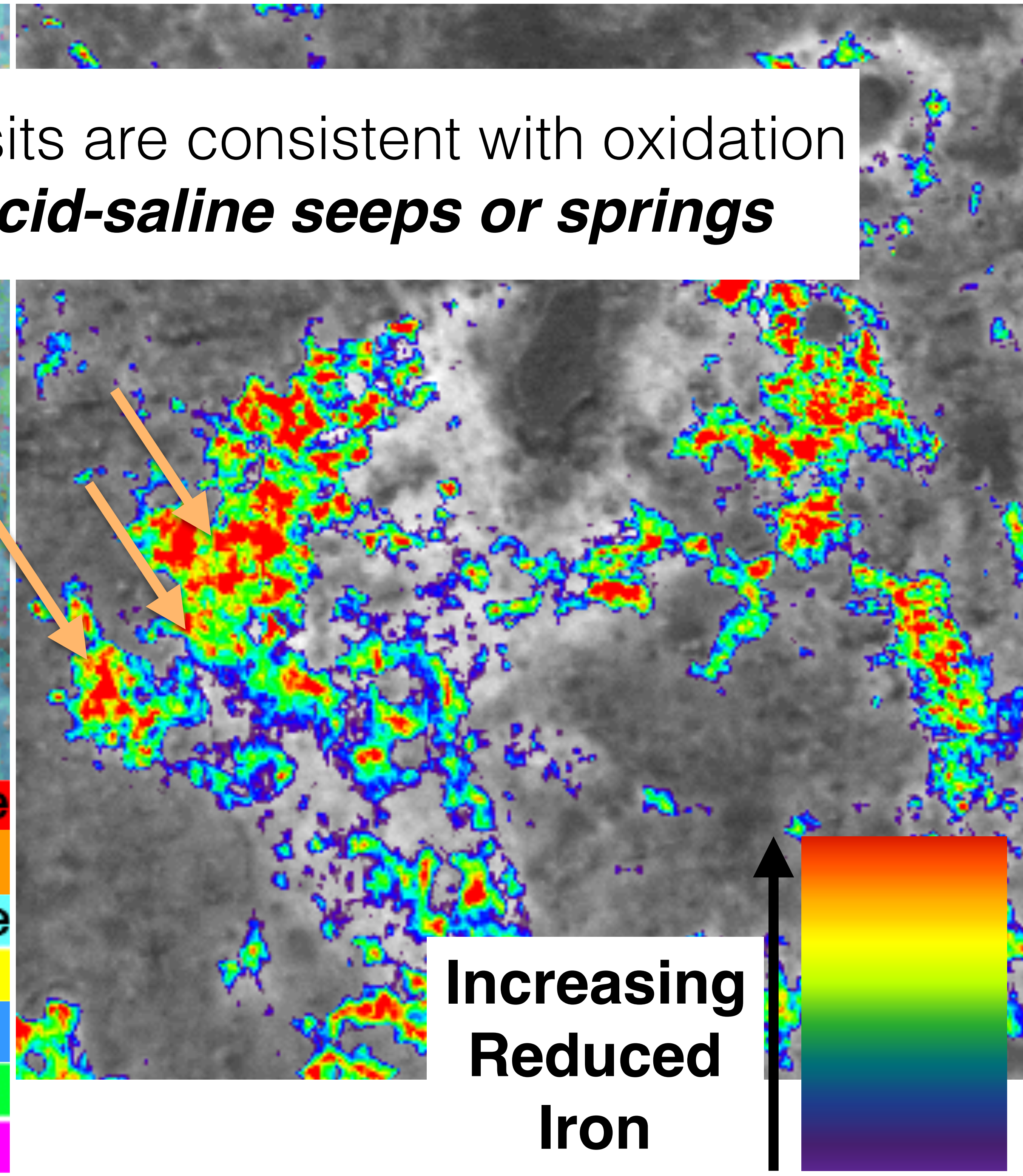




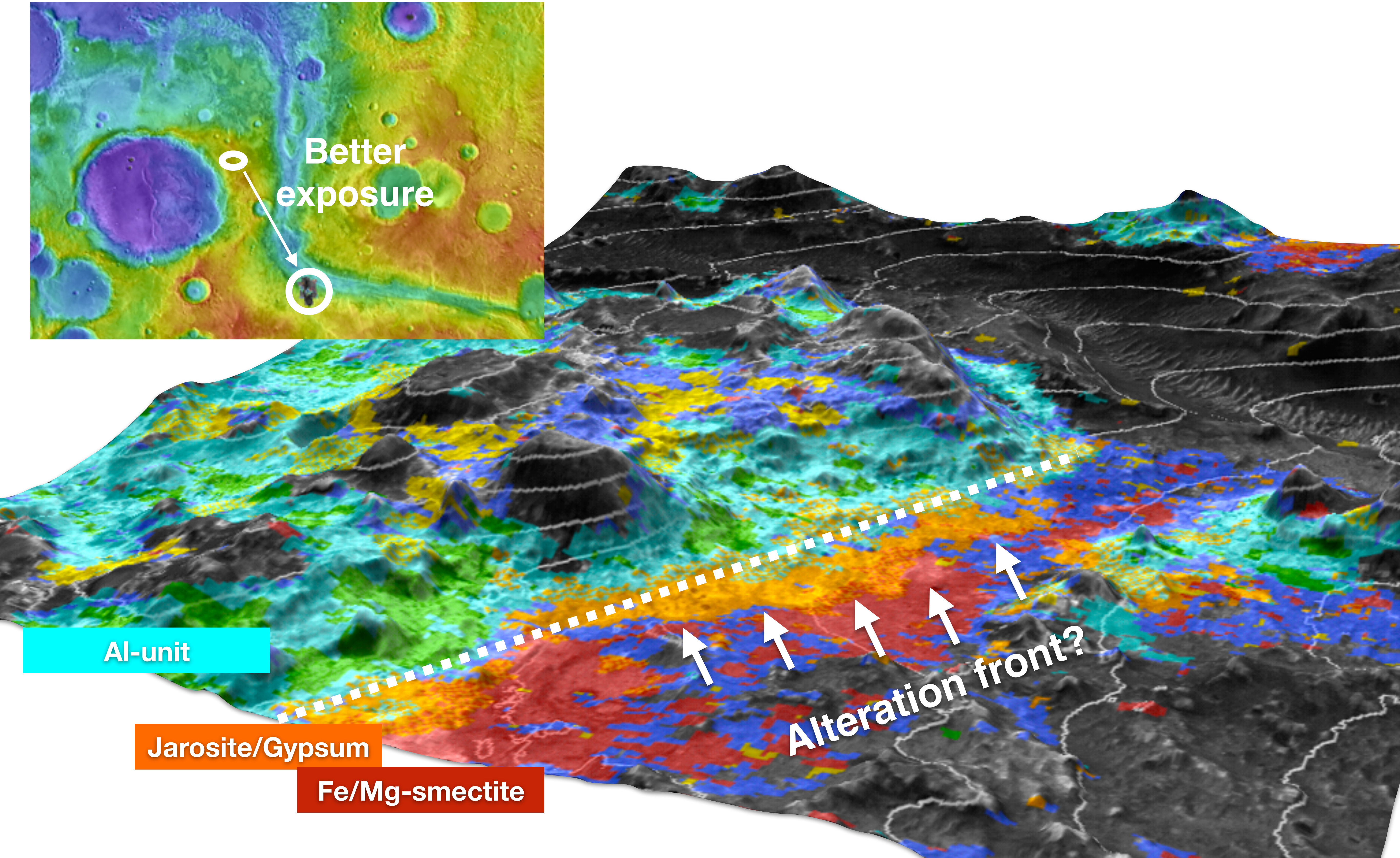
<u>Subsurface environment #2</u>:
Ferrous alteration zone at the top of the Fe/Mg unit is consistent with a reducing aquifer perched at the contact

Nearby jarosite/gypsum deposits are consistent with oxidation of reducing fluids, ***e.g., at acid-saline seeps or springs***

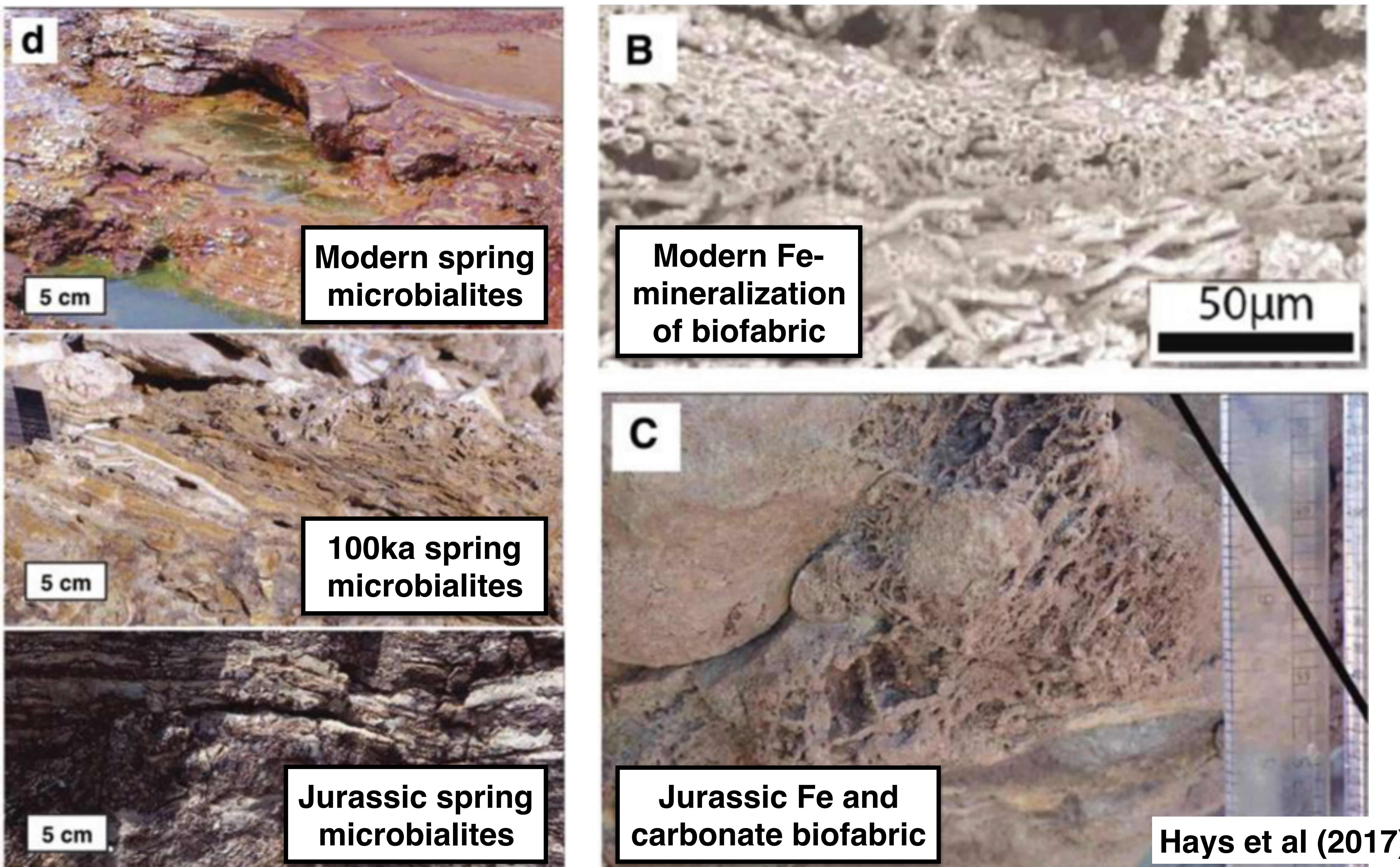




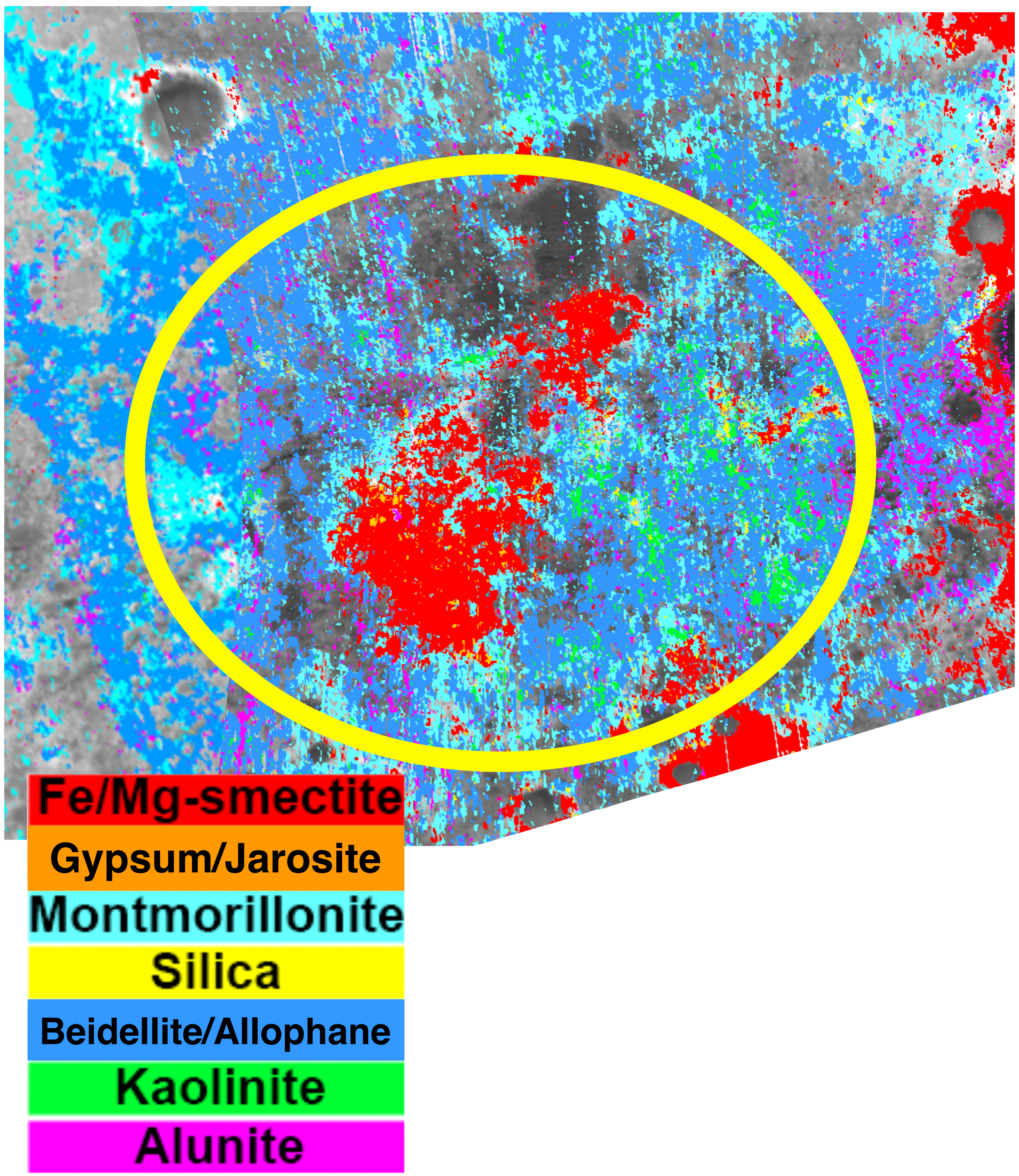
Fe/S redox gradients that form ferric sulfates are a key energy source for microbes, who mediate many of these reactions



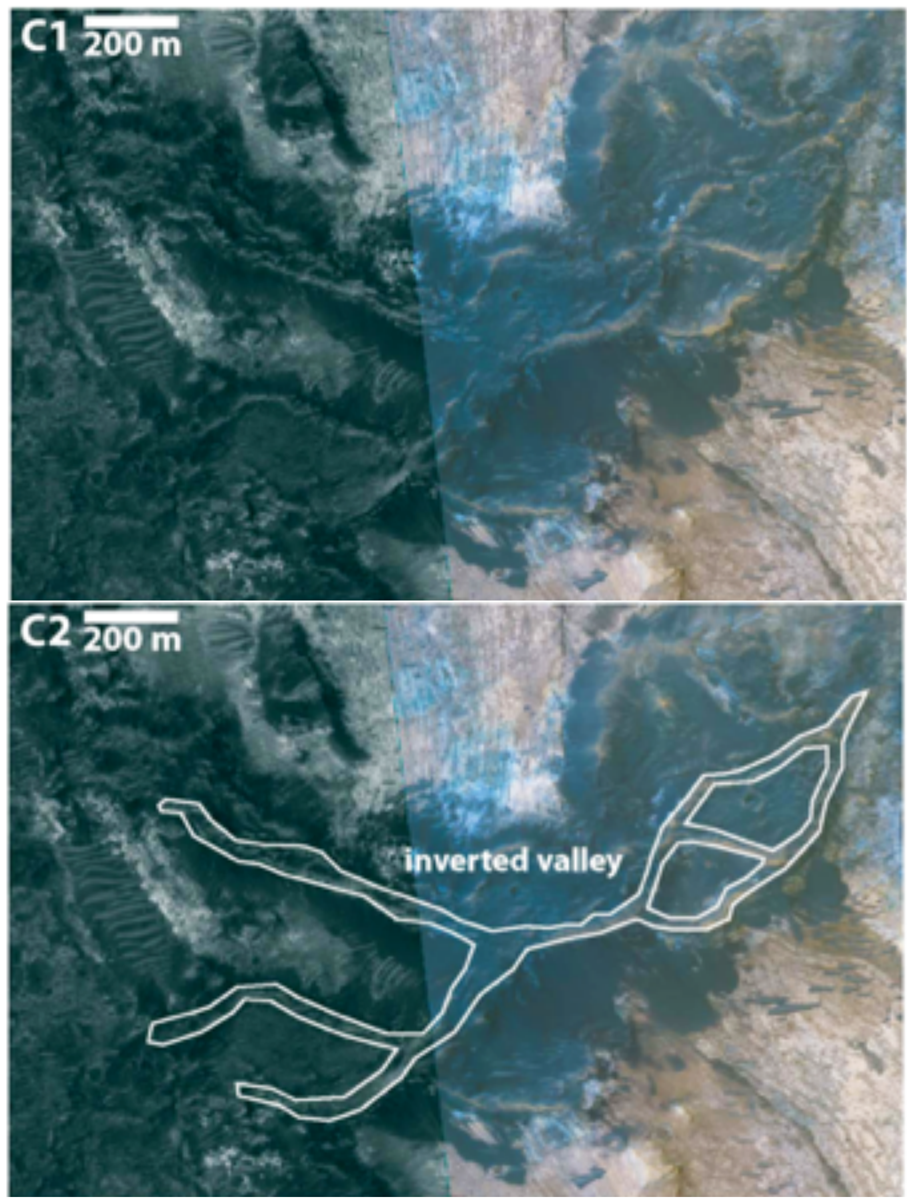
Springs are excellent sites for preservation of morphologic, organic, and other biosignatures.



Surface environment #1: The mineral diversity of the top of the sequence is consistent with a diverse suite of aqueous environments

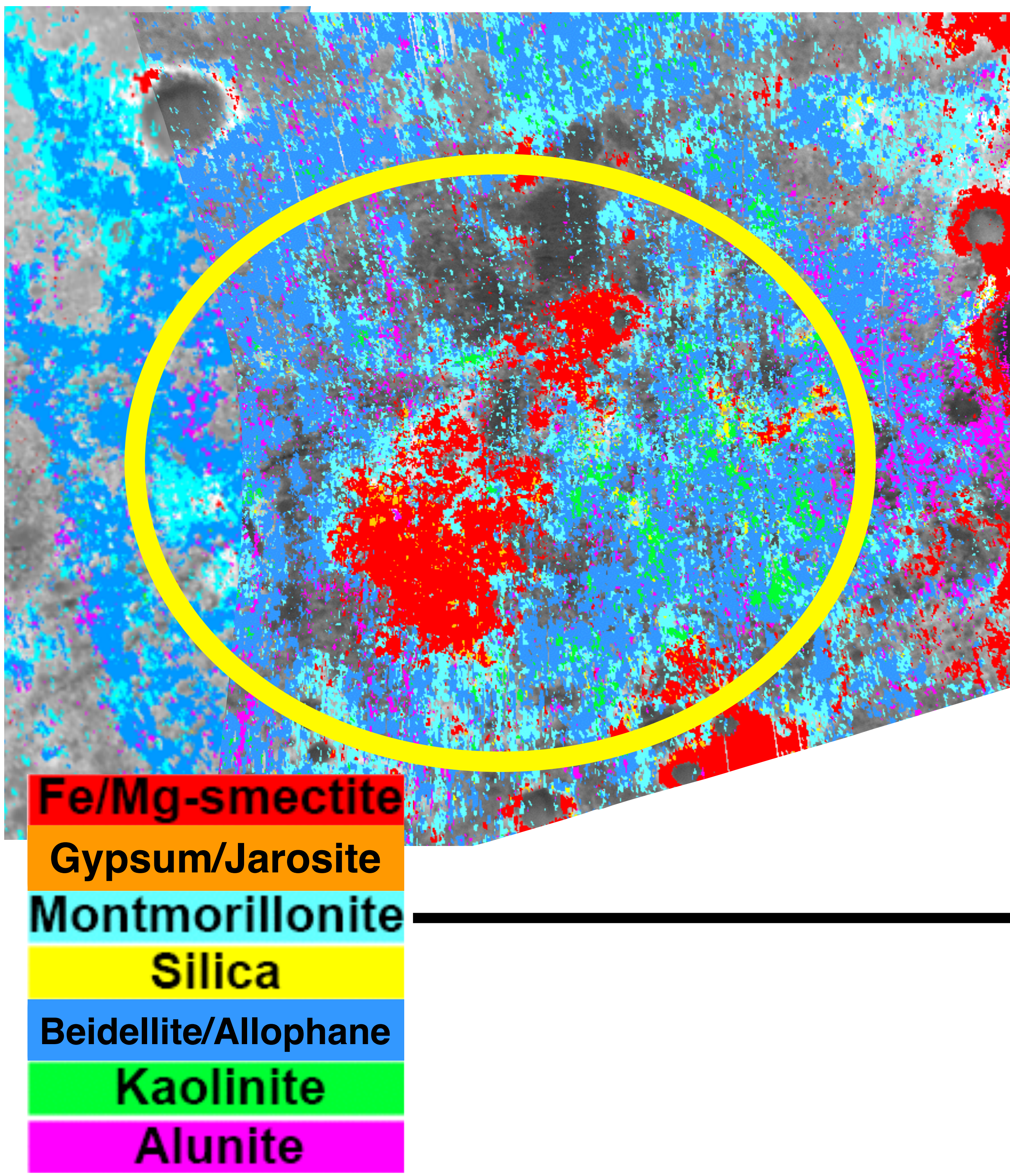


Inverted channels are associated with the top of the sequence, preserved by overlying mafic cap

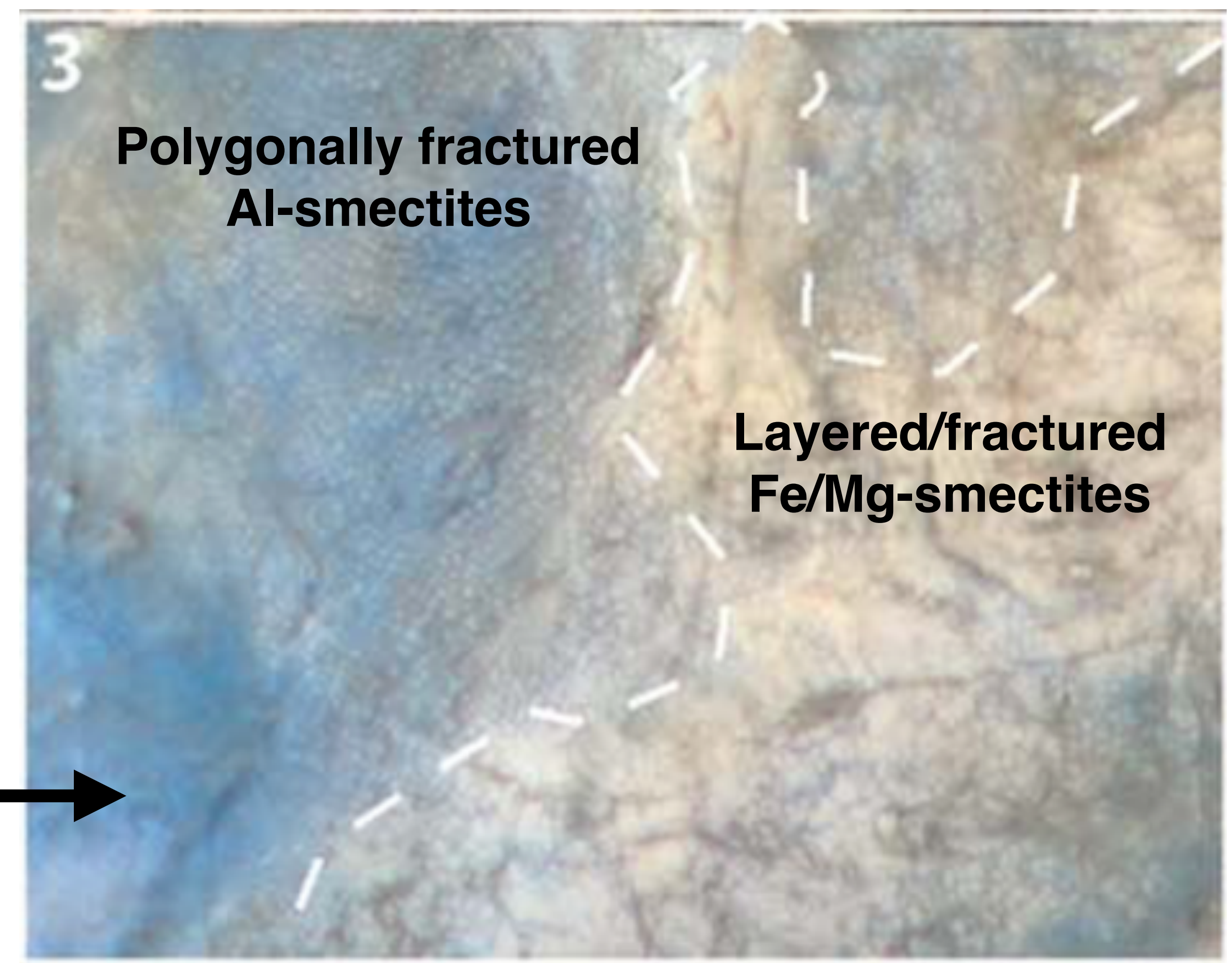


Loizeau et al (2015)

<u>Surface environment #1</u>:
The mineral diversity of the top of the sequence is consistent with a diverse suite of aqueous environments



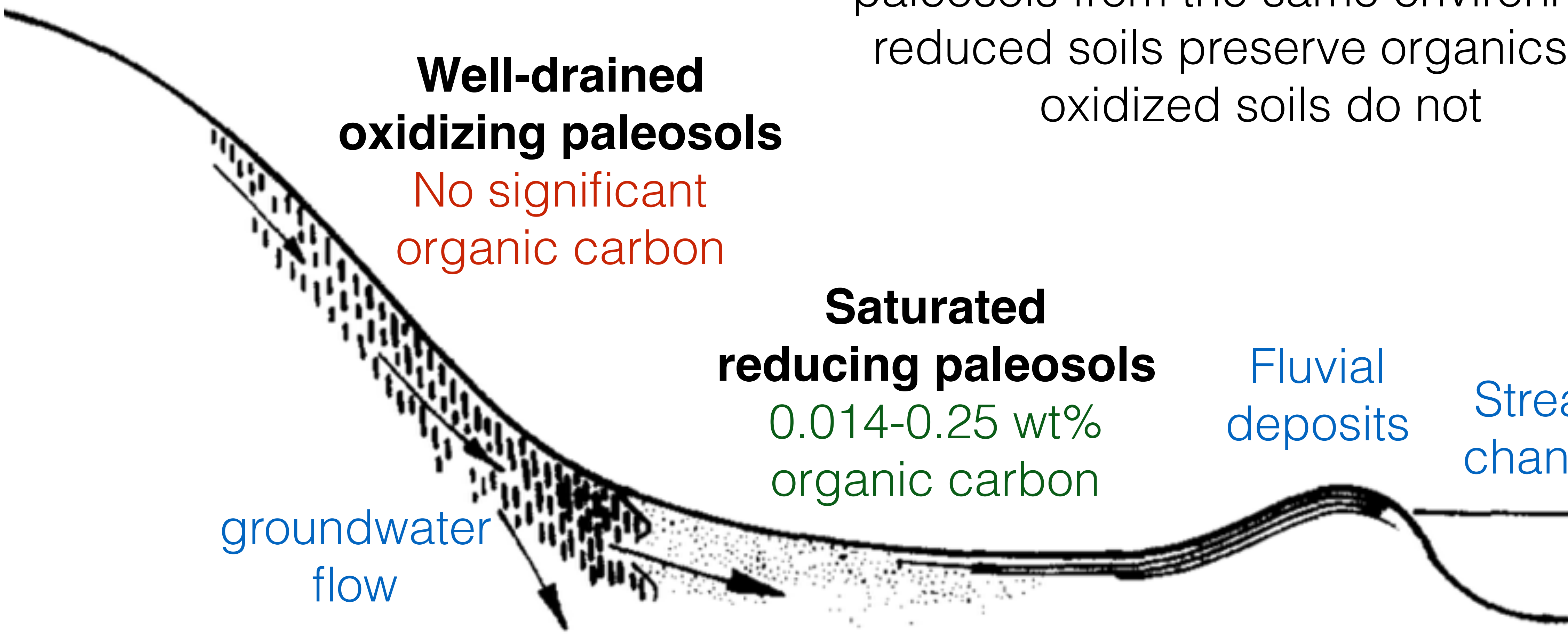
Most of the Al-unit at depth is consistent with Al-smectites, suggesting well-drained pedogenic weathering (paleosols)



Loizeau et al (2015)

Paleosols have highly variable preservation potential depending on the surface environment in which they were formed

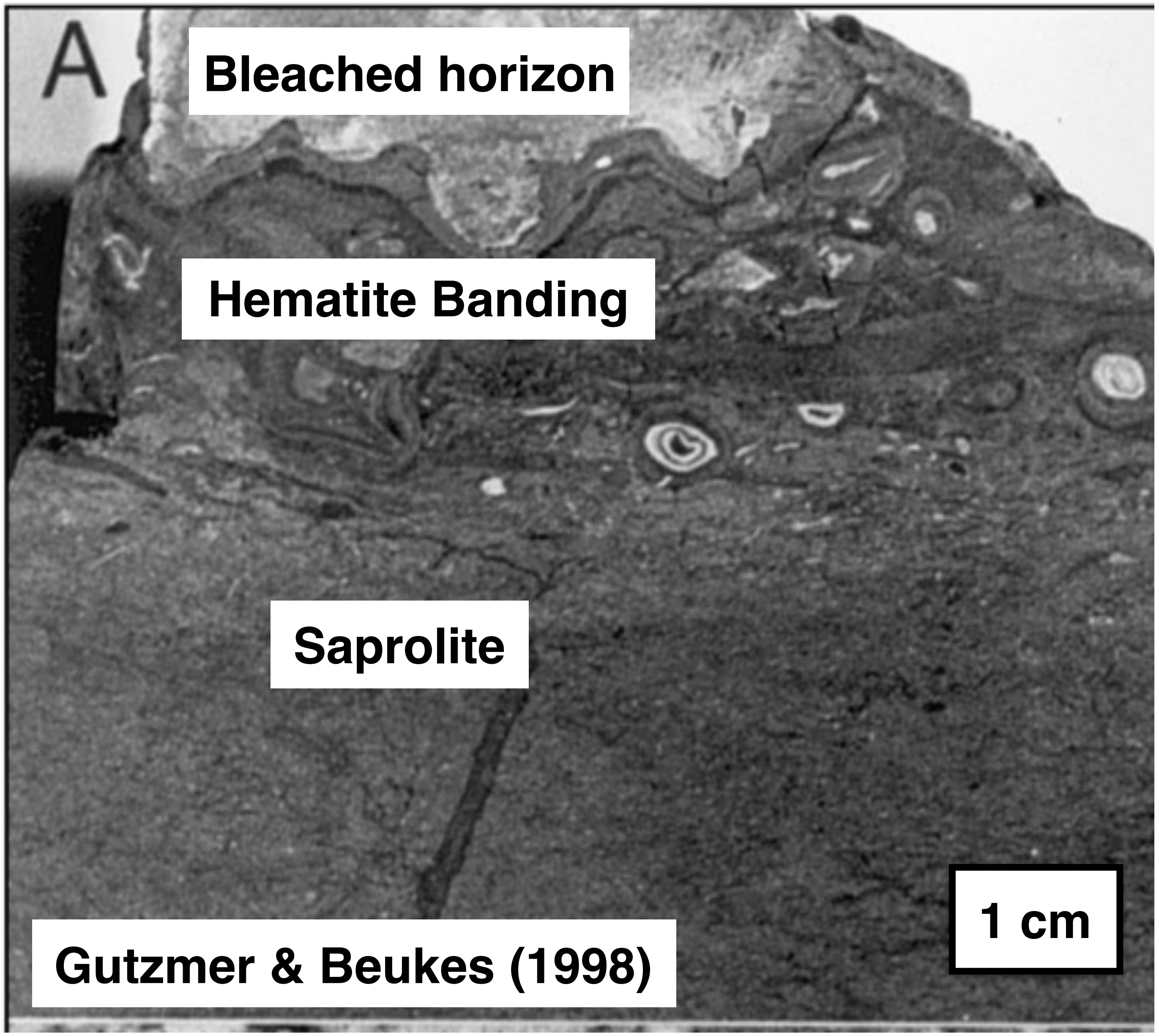
In a pair of 2.3 Gy Superior Craton paleosols from the same environment, reduced soils preserve organics but oxidized soils do not



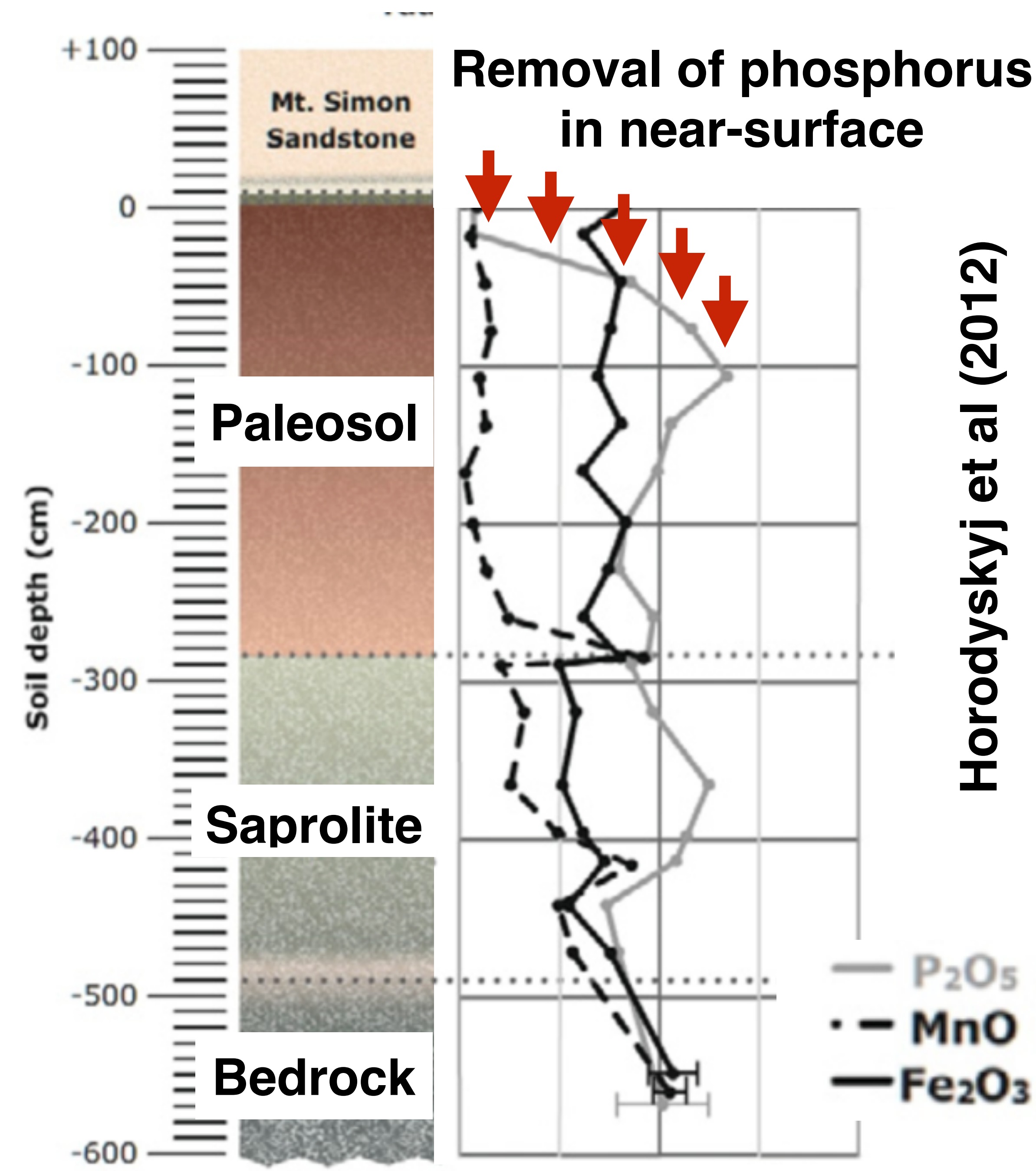
Gay & Grandstaff (1980)

Surface reducing and waterlogged conditions (seasonally or perennially) in a soil help to prevent oxidation of organics prior to burial

Oxidized soils are not inherently good sites of organic preservation, but can preserve chemical biosignatures



2.0-2.2 Gy Kappvaal Craton laterites contain “bleached” Fe-poor upper horizons attributed to organic acids from surface microbial communities

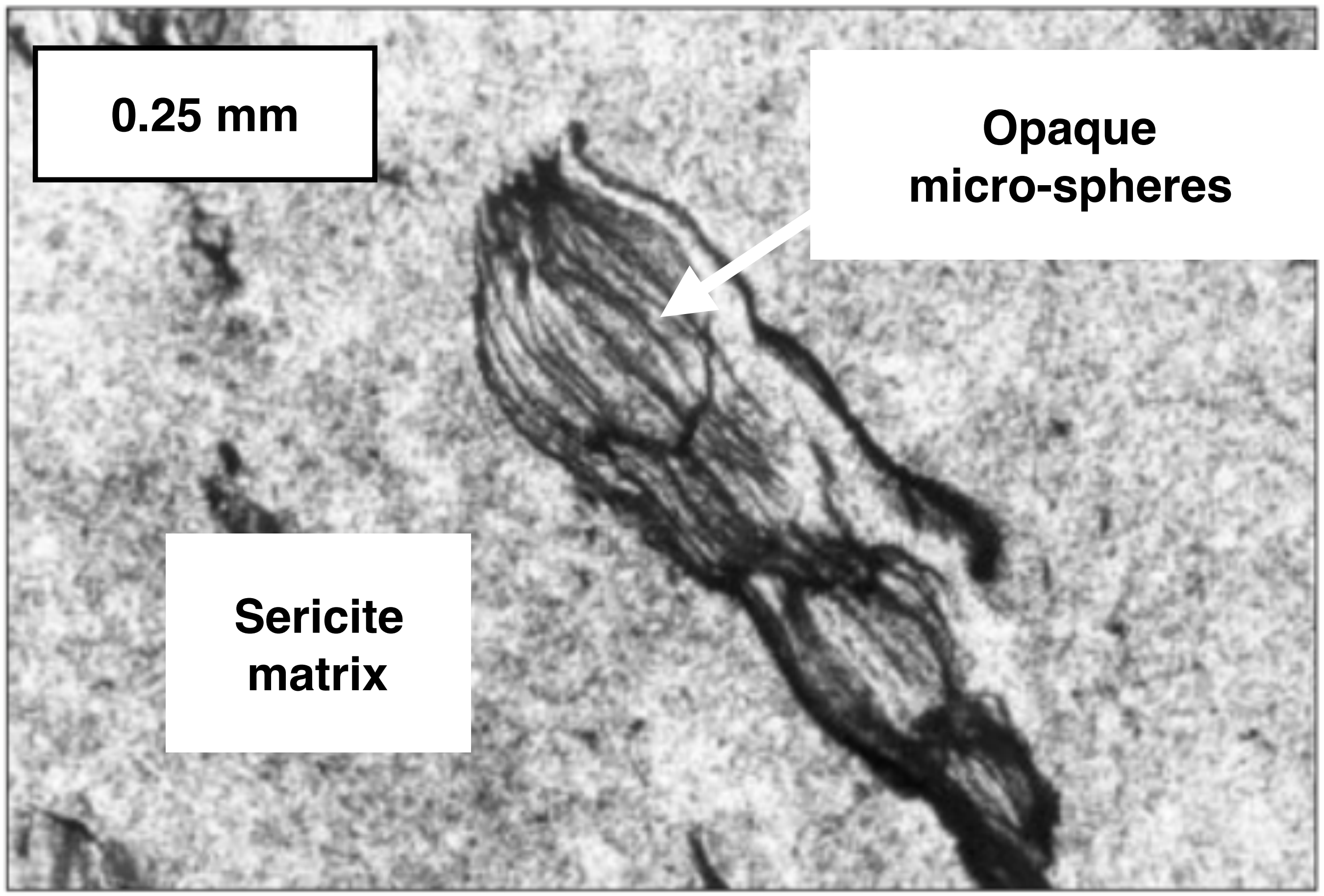


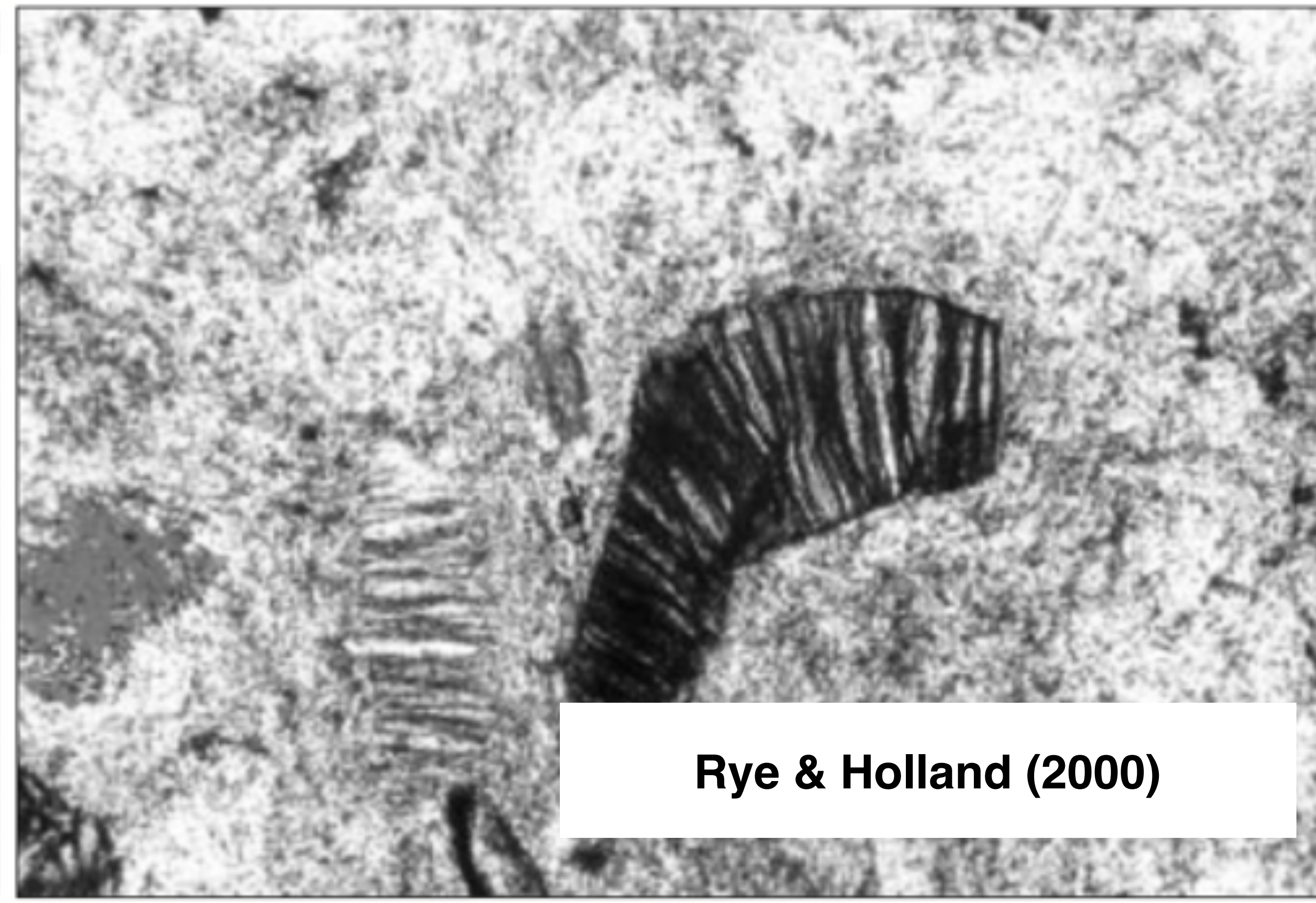
Phosphorus depletion could indicate biotic uptake, as in this 500 My S Dakota paleosol

Key ingredients for preserving microbial organics in terrestrial Archean/Proterozoic surface environments:

(1) Surface was reducing and inferred to be water saturated

(2) Rapid burial by a non-abrasive process (ash, lava, etc.)



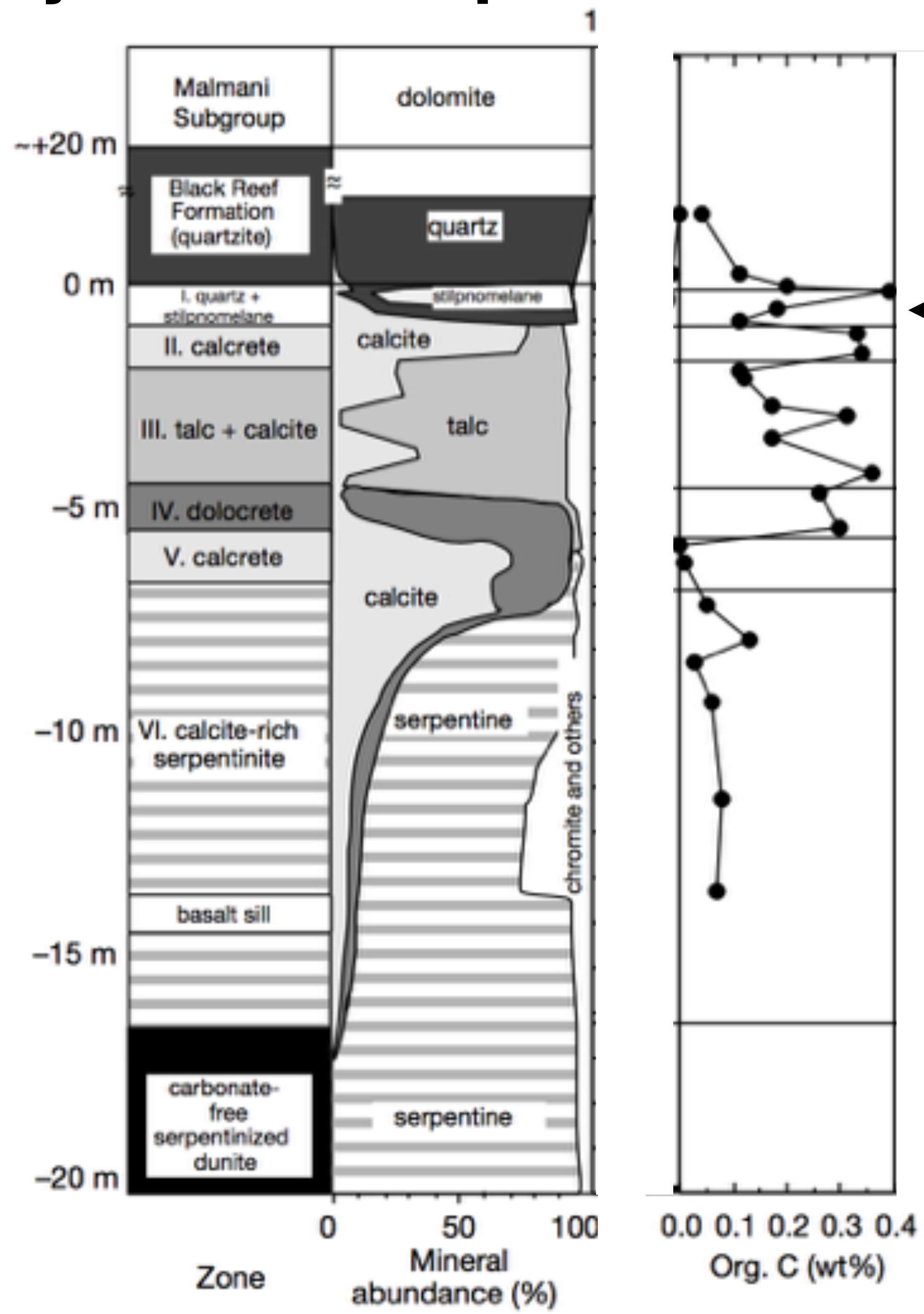


Example:

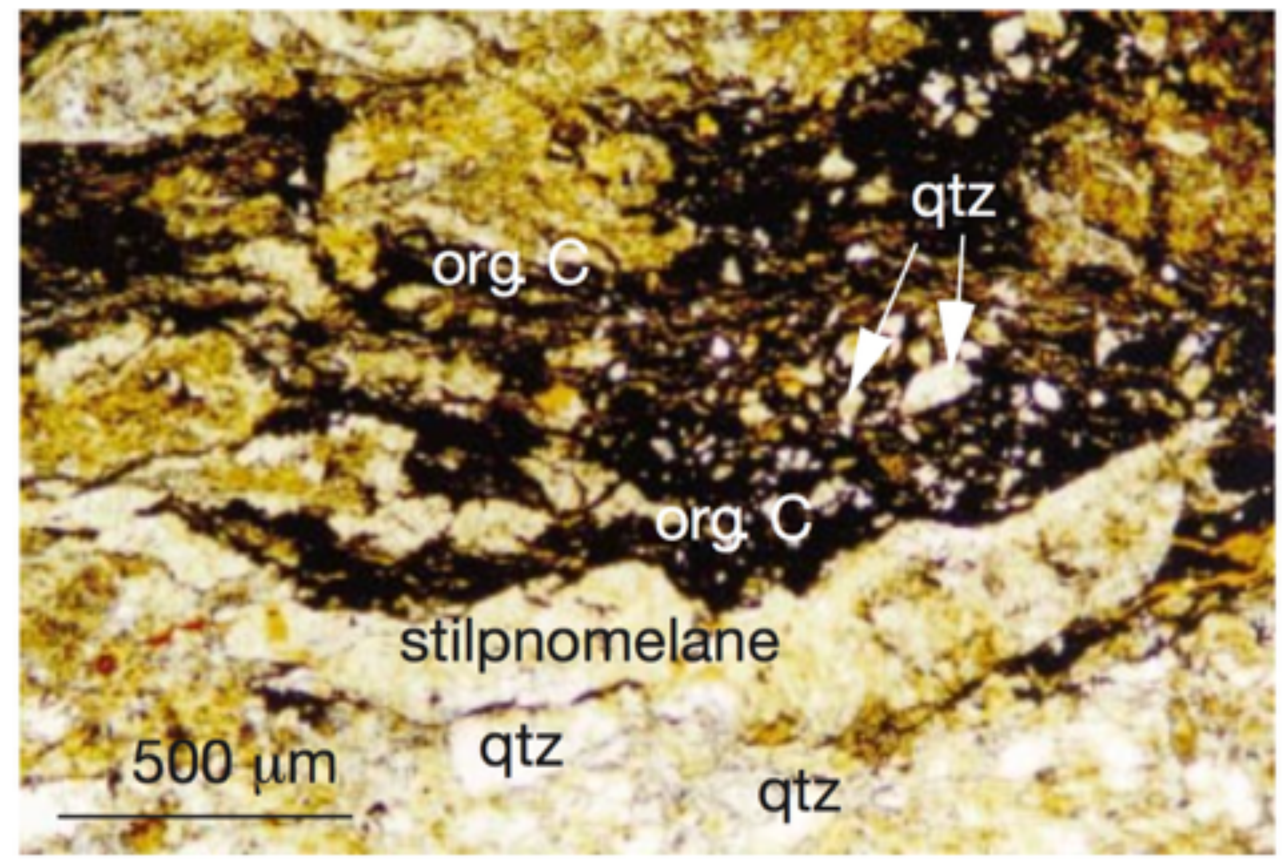
- This 2.76 Gy paleosol on basalt in the Pilbara Craton preserves organic carbon (0.05-0.1 wt%)
- Carbon isotopes are consistent with methanotrophs
- Opaque filamentous structures are found in the upper meter of the paleosol, which is preserved due to an overlying basalt flow

Interactions between soils, groundwater, springs, and fluvial systems can produce a record of microbial activity

Paleosol
Playa
Paleosols
Playa
Bedrock



Association of organic matter with clays in the paleosols

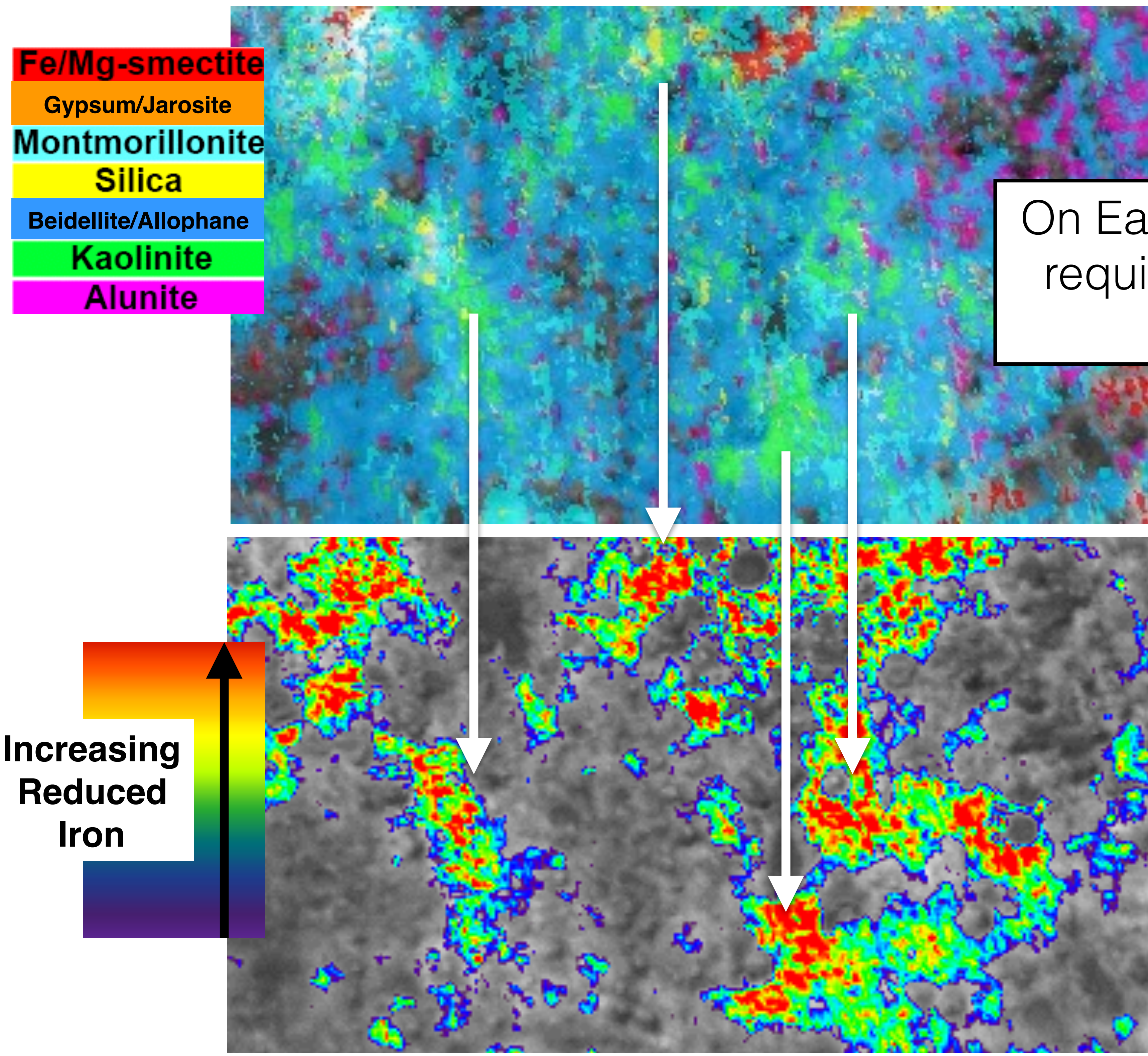


Watanabe et al. (2000)

Example:

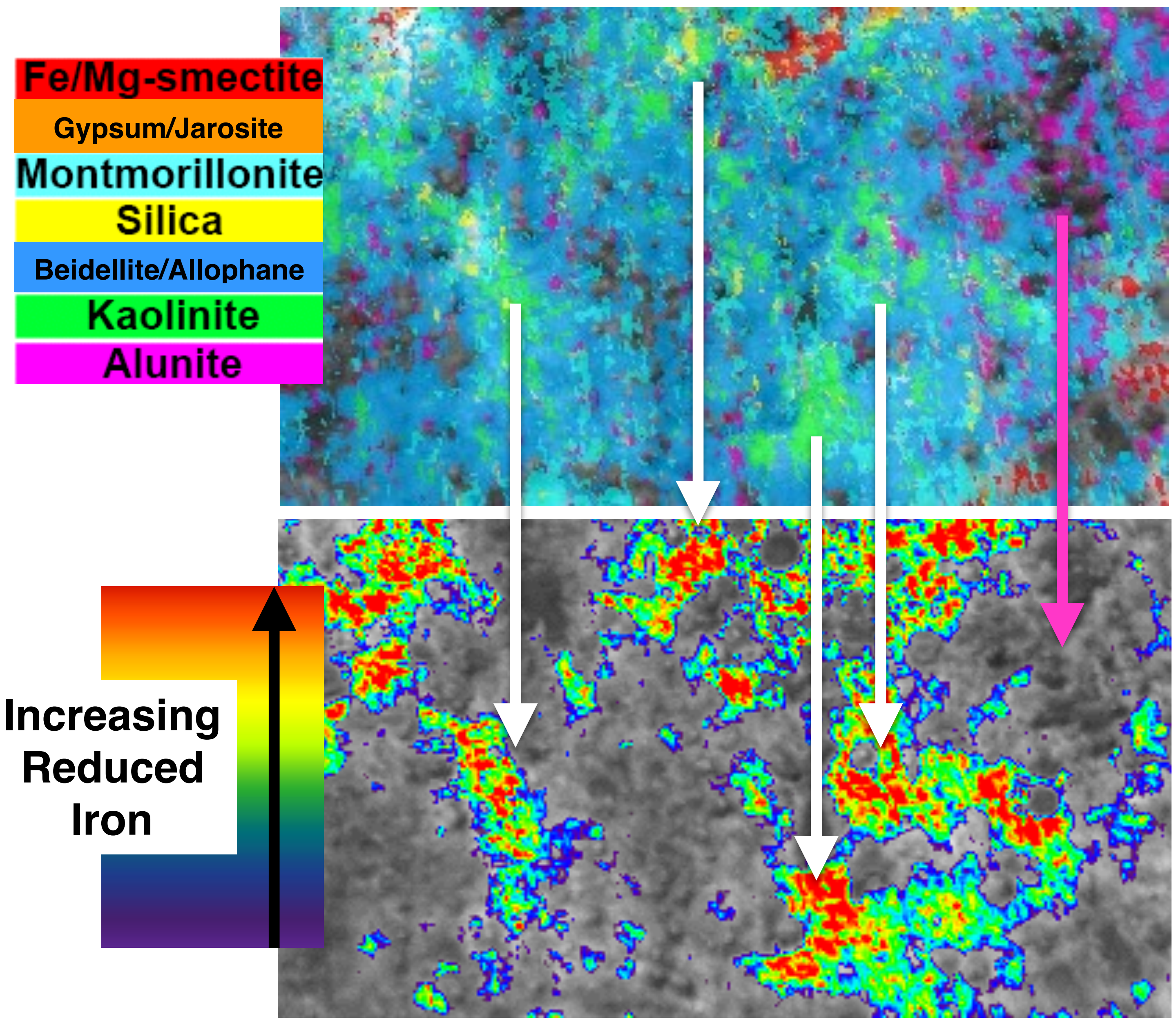
- 2.6-2.7 Gy Kaapvaal Craton interfingered paleosols and evaporites on serpentinized dunite preserves 0.1-0.36 wt% organic carbon
- Interpreted to be from sub-aerial microbial mats based on associated with clays

At Mawrth, the association between kaolinite and ferrous alteration phases suggests long-term weathering in a saturated and reducing surface environment

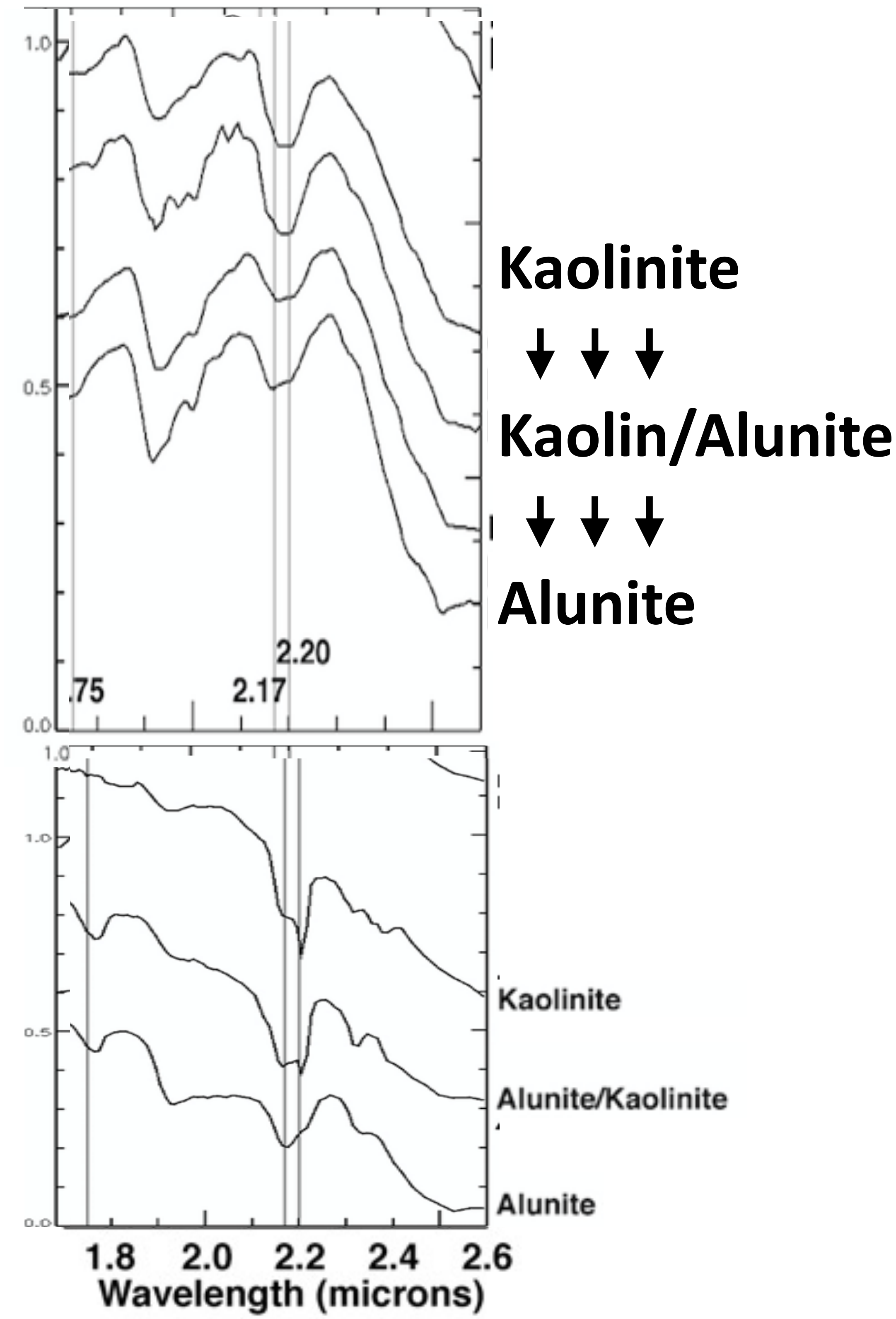


On Earth (e.g., Hawaii), kaolins can require hundreds of thousands of years (or more) to form

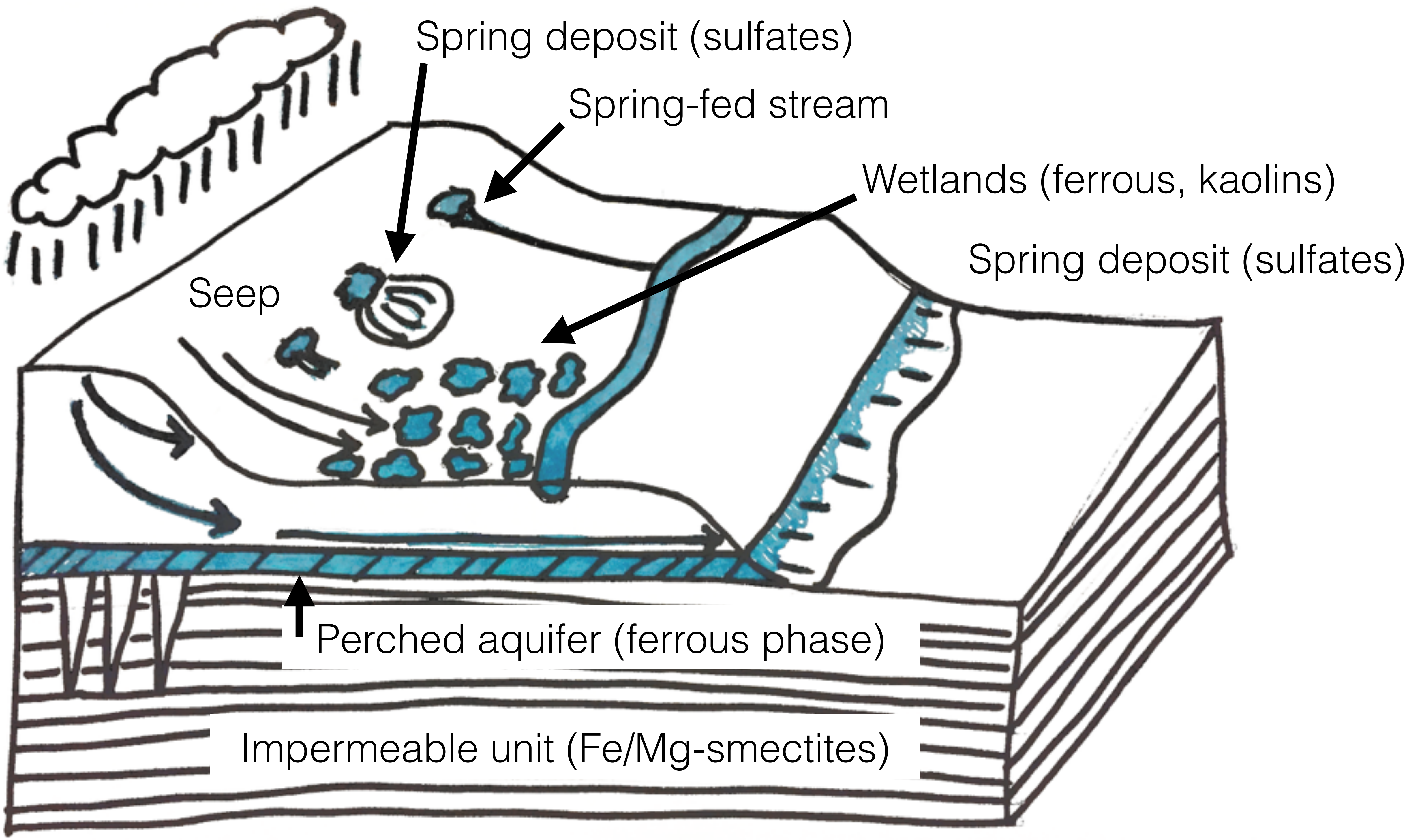
Kaolinite grades into alunite, consistent with oxidation of these Al-rich reduced phases in a surface redox gradient.



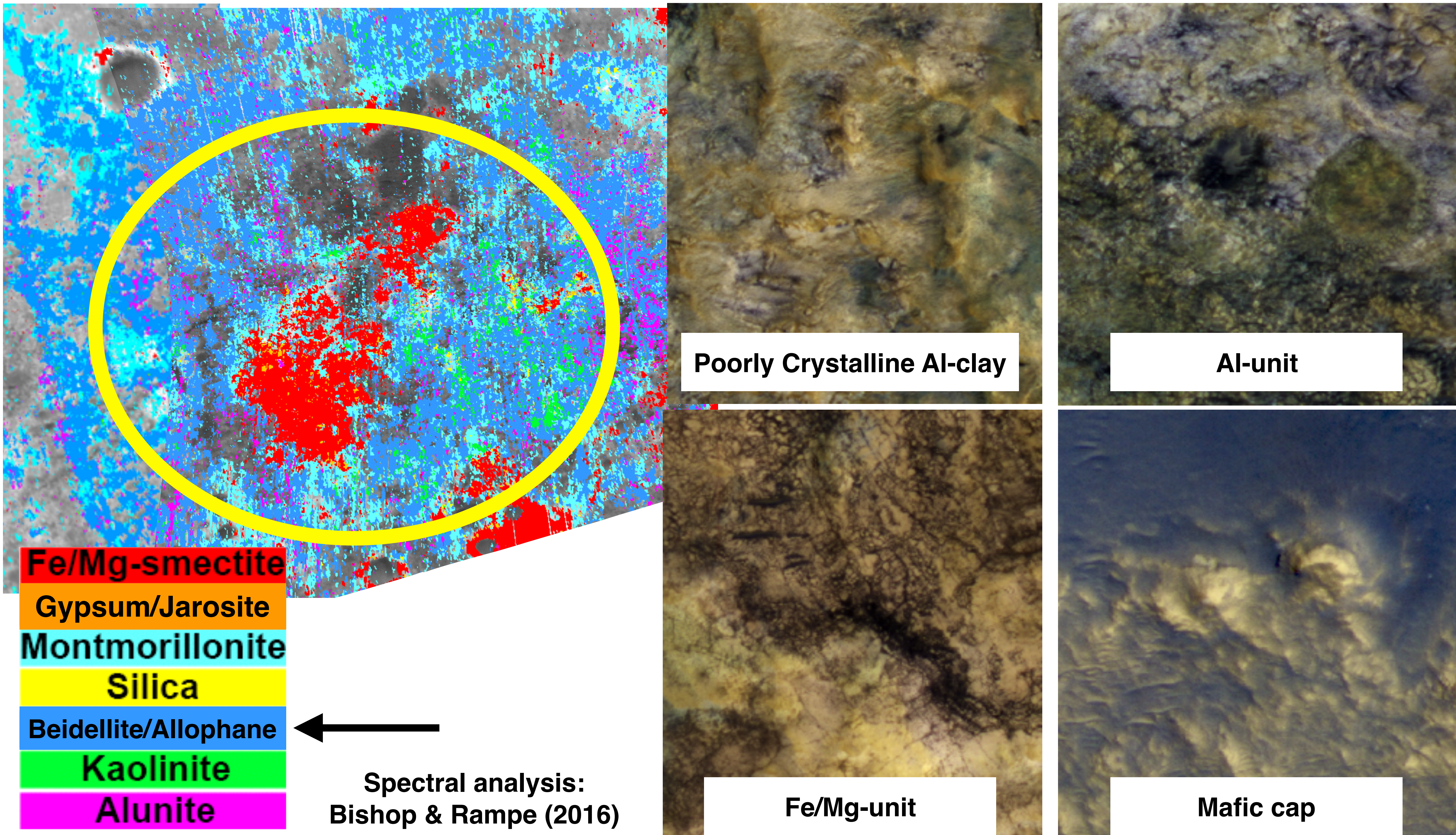
This assemblage (kaolins; reduced phases, including sulfides; alunite) is common in slightly acidic but reducing wetlands on Earth



Together, these diverse mineral phases suggest a diverse suite of aqueous environments powered by surface water/ groundwater interactions - streams, wetlands, springs.



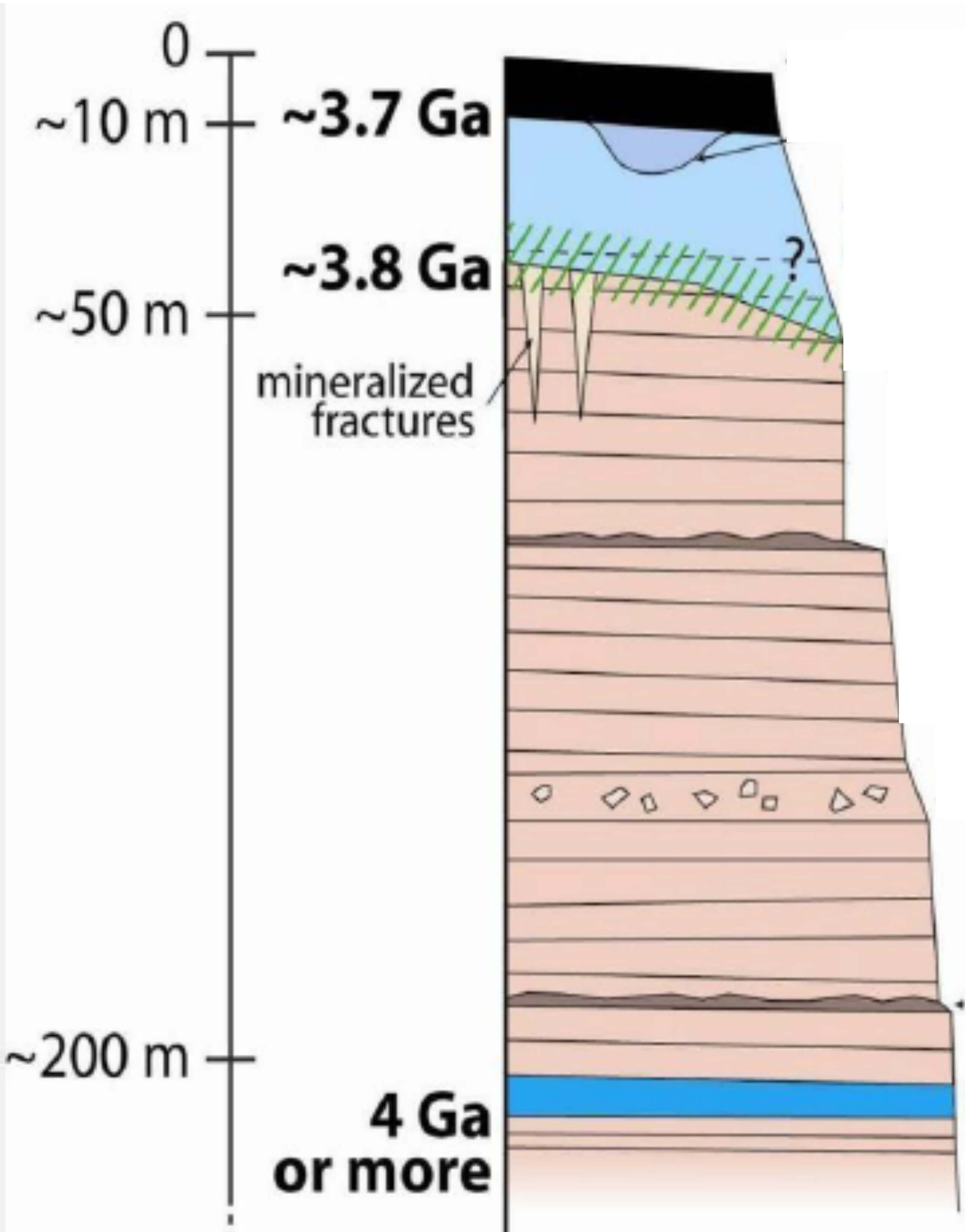
The terminal aqueous environment was buried by subsequent units - less crystalline Al-clay unit (paleosol?) and mafic cap (pyroclastic?). Good for preservation!

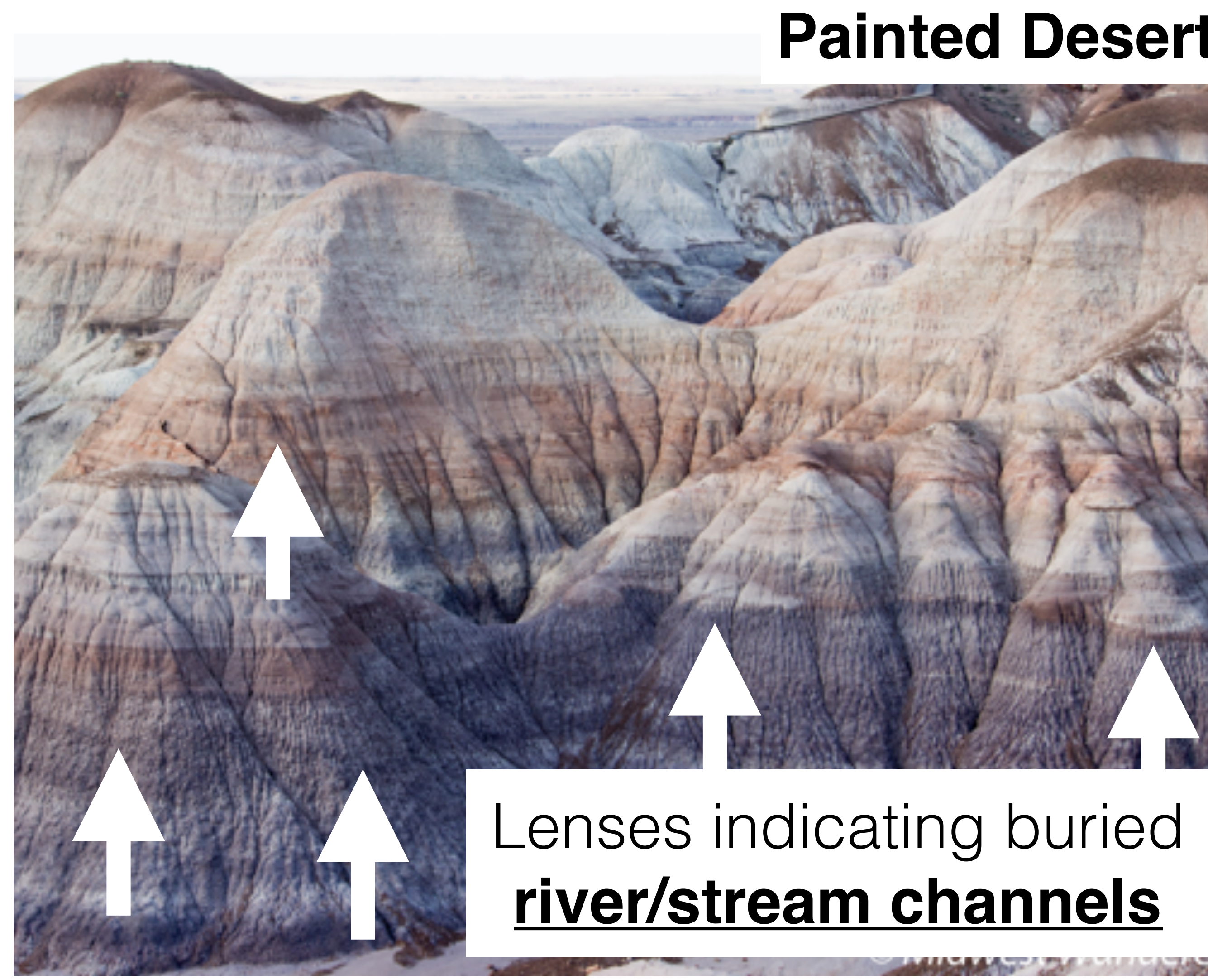


Spectral analysis:
Bishop & Rampe (2016)

Surface environment #2:

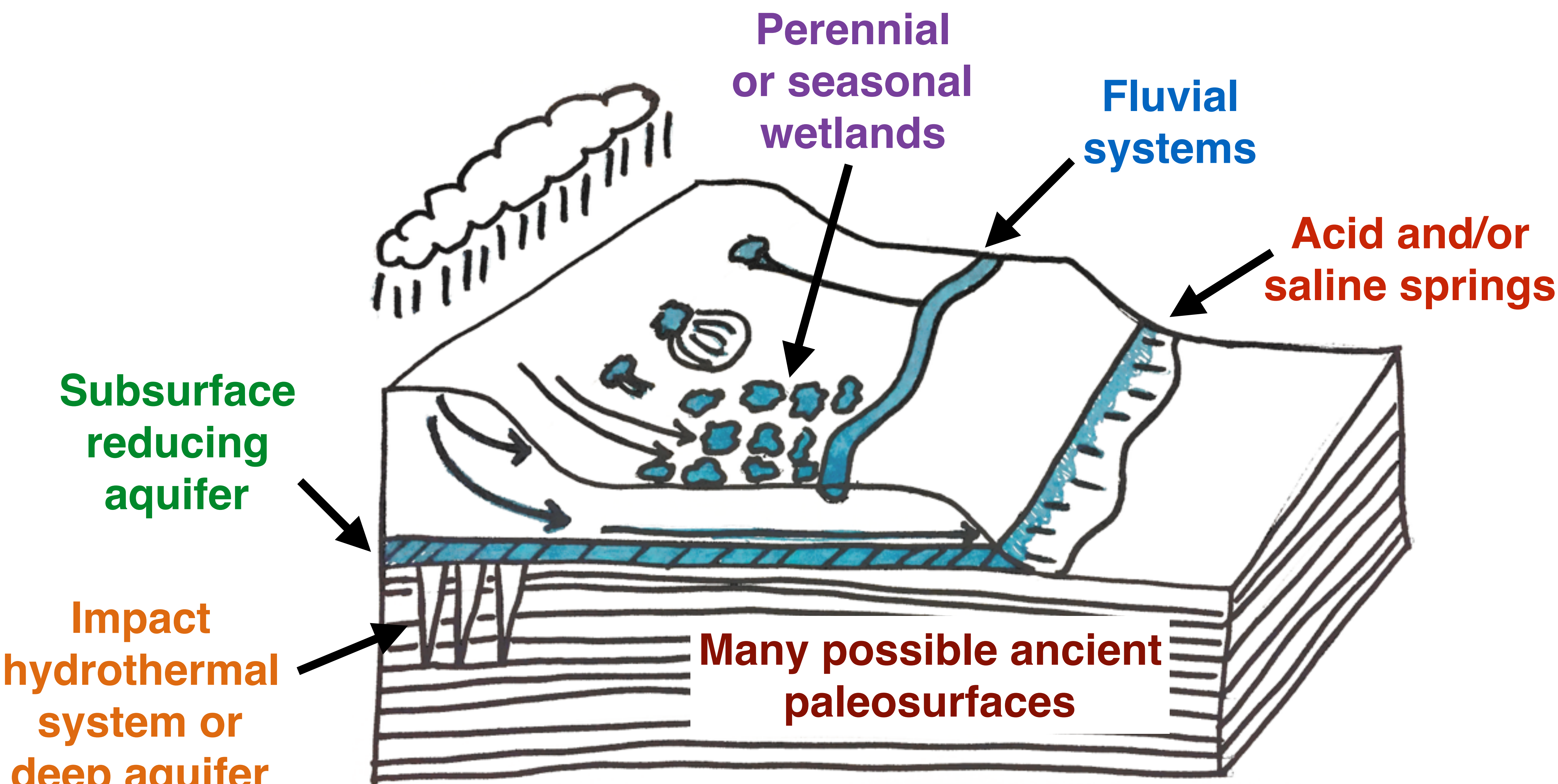
Rapidly buried Nochian paleosurfaces throughout the clay stratigraphy could preserve organics from surface communities and other aqueous environments.





Layering, cratered surfaces, and sulfates interbedded with Fe/Mg smectites suggest that habitable paleosurfaces may be present

The Mawrth Vallis landing site preserves diverse surface *and* subsurface habitable environments, spanning the Noachian, with equally diverse biosignature preservation mechanisms.



Mawrth Vallis also provides key constraints on the origin of Noachian crust and the persistence of wet climates *throughout* the Noachian.